Feeds & Feeding :- A Hand book
for the student and stockman

by

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starch and is therefore often called "animal starch." Normally, from 3 to 7 per cent of the weight of the liver is glycogen. Some glycogen is also formed in the other tissues of the body, especially the muscles. The glycogen in the muscles is used in the production of muscular work, as is described in Chapter X.

The glucose in the general blood circulation is continuously removed to nourish the various body tissues. To replenish the supply of glucose in the blood the glycogen is gradually changed back to glucose. This is then given out to the blood, as needed to keep the glucose content approximately constant. (The blood of cattle and sheep normally has 0.30 to 0.70 parts of glucose per 1,000 parts. That of swine and horses may be higher, and that of poultry has twice as much or more.[5])

44. Digestion of cellulose and pentosans.—No enzymes produced by the digestive tract are able to digest cellulose and pentosans, which form the cell walls of plants and make up a large part of all roughages. However, these substances are attacked by bacteria in the first three compartments of the stomach of ruminants, in the caecum and colon of the horse, and to a lesser extent in the large intestine of other animals. The number of bacteria in the rumen contents is tremendous. Each ounce of the contents may have trillions of bacteria.

These bacteria break down the cellulose and pentosans into organic acids (chiefly acetic acid) and possibly to a small extent into simple sugars. In this process gases (principally carbon dioxide and methane) are formed and heat is produced.

The organic acids serve as food to the animal, the same as sugars, but the gases are of no value. The heat produced is an entire waste, unless the animal needs this heat to maintain its normal body temperature. Recent studies show that some absorption of soluble nutrients, such as organic acids, can take place from the stomach of ruminants, but most of the absorption is from the small intestine.

The ability of livestock to use the fiber and pentosans in their feeds depends on this bacterial digestion. It is therefore of great importance in the nutrition of cattle and sheep, and is the fundamental reason why they can live chiefly on roughage. Not only are the fibrous cell walls thus utilized for food, but also this digestion sets free the nutrients contained inside the cells, so they can be more easily acted on by the digestive juices in the true stomach and in the intestines. The lignin in feeds is digested only to a very small extent. (**11**)

Some digestion of protein into simpler compounds occurs in the bacterial action, the bacteria building the simpler compounds into protein in the bacterial cells. The bacteria are also able to use simple forms of nitrogen compounds, such as urea, in their growth, building them into protein. (**128**) Also, starch-like complex carbohydrates may be formed in some of the bacterial cells.

The bacteria and other microorganisms are mostly digested in the true stomach (abomasum) and the small intestine, thus furnishing nutrients to the ruminant animal. In this manner a ruminant can use such a simple nitrogenous compound as urea to replace part of the protein in its food. (**112**)

Investigations have shown that all of the B-complex vitamins are formed by the rumen bacteria in their growth and become available to the ruminant through the digestion of the bacteria. (**208**) Therefore the ruminant may need no B-complex vitamins in its food.

Not only do the bacteria digest cellulose and pentosans, but also they may attack starch and sugar. This action is detrimental, for these nutrients would be digested more efficiently later on in the small intestine, while in the bacterial digestion an appreciable part of their feeding value is lost through the heat and gases produced in the fermentations.

The fact that practically no ptyalin is present in the saliva of cattle and sheep is advantageous to them. If their saliva converted starch into sugar, much sugar would be formed in the rumen.

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This would then be attacked by bacteria, with a resultant loss of nutrients.

In addition to the digestion in the rumen caused by bacteria, more or less digestion is undoubtedly produced by the enzymes contained in some foods, such as the cereal grains, for the moisture and warmth of the rumen are favorable to enzyme action in general. Also, certain protozoa (microorganisms larger in size than bacteria) thrive in the food mass in the rumen and apparently aid in the digestive processes.

Ruminants get rid of most of the gas produced in the fermentations through belching, though some is absorbed into the blood and escapes by way of the lungs. Sometimes this belching process does not occur normally, and bloat results, as is described later. (49)

45. Studies on digestion in rumen.—Recently many scientists have conducted studies on the various factors that affect the efficiency of digestion in the rumen.[6] Some of the experiments have been with a so-called "artificial rumen," in which digestion occurs similar to that in the rumen of an animal. Other studies have been with animals operated on to make a permanent opening, or fistula, into the rumen. In still other experiments, the effects of various feeds or food additions have been determined in digestion trials with normal ruminants.

These investigations have shown that the rumen bacteria have very specific nutrient needs for their maximum development, just as the host animal itself has definite nutrient requirements. A deficiency in the rumen contents of a nutrient which the bacteria need will decidedly decrease the bacterial growth and therefore lessen the digestion in the rumen.

For example, a lack of protein or of a substitute simpler form of nitrogen, such as urea, will decrease digestion of cellulose. Similarly, digestion will be impaired by a lack of essential minerals, including the trace minerals. As shown later, the chief need for cobalt by ruminants may be to make possible normal development of the rumen bacteria. (175)

In experiments with the artificial rumen in which a purified culture solution has been used, containing presumably adequate supplies of protein and minerals, the digestion of cellulose has been increased by the addition of several substances. These include rumen liquid from a normal animal, grass juice, alfalfa hay or alfalfa ash, valeric acid and certain other fatty acids, and partly digested protein. The nutrient requirements of the rumen bacteria therefore seem complex. Fortunately, their needs are readily met when ruminants are fed ordinary well-balanced rations that include good roughage.

The experiments have shown that for satisfactory digestion of poor roughage, such as ground corn cobs, straw, cottonseed hulls, or even very poor late-cut hay, adequate supplementation is needed with protein or another source of nitrogen, and with minerals, including perhaps trace minerals. The addition to such roughage of a small amount of high-quality roughage, such as good alfalfa hay, will generally increase rumen digestion greatly, through furnishing needed protein, trace minerals, or some unknown factor needed in the bacterial growth.

On the other hand, when there is an adequate proportion of good roughage in a properly balanced ration, no special supplementation is required to ensure efficient digestion.

At birth, the rumen is developed but little, and there are few fiber-digesting bacteria. A very young calf can therefore make but little use of hay or other roughage until its rumen develops. Opinions differ as to whether there is generally any benefit from inoculating young dairy calves with cuds from mature cattle. (1123) Sometimes veterinarians use the transfer of rumen contents from a normal animal in treating cases of severe indigestion in cattle.

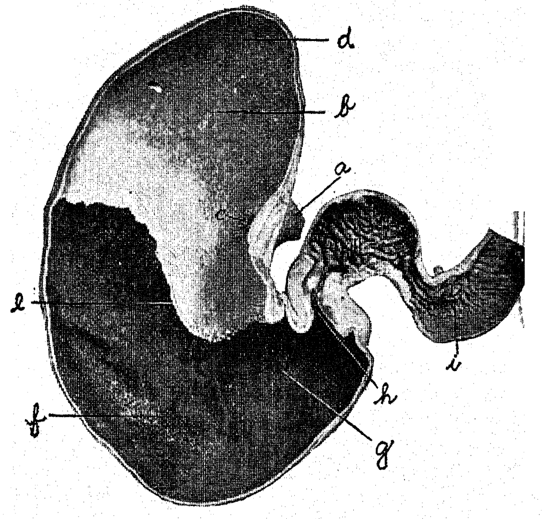
46. Digestion and absorption of protein.—The proteins of the food are first attacked in the stomach by pepsin, an enzyme of the gastric juice, which splits them into proteoses and peptones. These are soluble and simpler in com-

position than the proteins, but are still very complex in structure.

The proteoses and peptones, together with any protein that escapes action by pepsin, pass into the small intestine. There trypsin, an enzyme in the pancreatic juice, not only cleaves the undigested protein into proteoses and peptones, but also digests the proteoses and peptones further, splitting them into amino acids, which are much simpler. Through the action of trypsin and of

In the case of suckling animals or others consuming milk, rennin, which is an enzyme in the gastric juice, is of importance. This curdles milk, changing it from a liquid to a solid, so that it cannot pass too rapidly through the stomach and thus escape digestion.

47. Digestion and absorption of fats.—The fats of foods undergo no appreciable digestion until they reach the small intestine. Here, through the aid of the bile produced by the liver, the fat



LONGITUDINAL SECTION OF STOMACH OF THE HORSE

A, Esophagus, or gullet; b, esophageal region of stomach, in which no gastric juice is secreted; c, entrance of gullet; d, left extremity of stomach; e, boundary between esophageal region and portion of stomach secreting gastric juice; f, g, fundus gland region and pyloric gland region, in which gastric juice is secreted; h, pylorus, or ring of muscles closing the stomach; i, entrance of pancreatic and bile ducts. (From Sisson, "Anatomy of the Domestic Animals.")

other enzymes in the pancreatic juice and the intestinal juice, practically all the protein that can be digested is broken down into amino acids. A little may be left in the form of peptides, which are relatively simple combinations of two or more amino acids.

The amino acids are soluble and are readily absorbed by the villi of the walls of the small intestine. They then pass into the blood and are carried to nourish all parts of the body. Small amounts of peptides may be absorbed in the same manner.

is emulsified, or broken up into very small droplets. Lipase, an enzyme in the pancreatic juice, which is activated by bile, then splits the fats into fatty acids and glycerol. These are absorbed by the villi of the intestine. It is possible that some unchanged fat may also be absorbed in emulsified form. In addition, small amounts of the fatty acids may unite with the alkalies in the digestive fluids to form soaps, which are readily absorbed.

In the villi the fatty acids are reunited with glycerol to form fat. The fat

is then carried chiefly in the lymph system to a vein near the heart, where it enters the blood circulation. (It is the opinion of some that in the process of absorption the fatty acids are converted into phospholipids, which are mostly changed to fat in the intestinal walls.) (14)

48. Minerals; vitamins; water.—The mineral matter in feeds that is not already soluble is dissolved to a greater or less extent by the hydrochloric acid in the gastic juice of the stomach. Further freeing of mineral nutrients occurs as the organic nutrients are digested by the several enzymes. Minerals are absorbed chiefly from the small intestine.

Little is known about the manner in which the vitamins are digested and absorbed.

Water requires no digestion, and it is absorbed along the digestive tract, chiefly in the small intestine.

49. Bloat.—Many studies have been carried on in an endeavor to determine the exact causes of bloat in ruminants and to find methods of preventing it.[7] However, many problems concerning bloat are still only partly solved.

Bloat results when the gases produced in the fermentations occurring in the rumen do not escape normally, but accumulate, causing great distension of the rumen. In severe bloat, death frequently results, and even when the animal does not die, production may be seriously reduced.

Cattle are somewhat more apt to suffer from bloat than sheep, and animals consuming a large amount of feed are more likely to bloat than those eating less. For this reason dairy cows in milk are more subject to bloat than dry cows or heifers, and ewes nursing lambs bloat more frequently than other sheep.

Legume pasture of certain kinds, especially before bloom, is most likely to cause bloat. Alfalfa and Ladino clover seem to cause more trouble than red, alsike, or sweet clover. Birdsfoot trefoil apparently does not cause bloat. Bloat rarely occurs on grass pasture, and there is usually little trouble on mixed legume-grass pasture if grass forms at least half of the forage and if the stand of grass is even and uniform throughout the pasture.

Pasturing a legume only after it has reached the blooming stage helps prevent the trouble. Bloat seems to be apt to occur when the growth of the legume has been very rapid during a period of warm, rainy weather.

If both stems and leaves of green alfalfa are eaten, bloat may not occur, while cattle grazing selectively and eating only the tops and leaves have trouble.

Although there is unfortunately trouble from bloat on pastures containing a large proportion of such legumes as alfalfa and Ladino clover, the greater yield and higher feeding value of these pastures more than offset this disadvantage, if due care is taken to prevent bloat.

It was previously thought that bloat was caused by an unusually rapid production of gas in the rumen, as a result of eating a large amount of lush, readily-fermentable green forage. Recent studies indicate, however, that bloat-producing feeds do not necessarily produce more gas. Bloat is caused by a failure to get rid of the gas rapidly enough. Some of the gas normally produced in the rumen is absorbed into the blood and escapes by way of the lungs, but most of it is expelled by belching.

Many cases of bloat are "frothy bloat," in which the gas is in very small bubbles, which are entrapped in the rumen contents. Much of the gas can then not be expelled by belching. Some believe that such a bloat is caused by saponins, which are substances that can produce a soapy froth.

The cause of death in bloat is not definitely known. The rise of pressure in the rumen is not apparently great enough to be the chief cause. Some believe that death may be due to the absorption of poisonous compounds produced in the rumen fermentation, or possibly to carbon monoxide or hydrogen sulfide, poisonous gases, which may be formed in small amounts.

It has been found that the juice of certain legumes, such as Ladino clover

or alfalfa, administered to cattle by means of a stomach tube, can cause bloat and also prevent muscular movements, such as produce belching.

One theory of bloat prevention is based on the belief that belching, like rumination, is initiated by stimulation of nerves in the rumen through irritation of coarse feed. When an animal eats a large amount of soft, succulent legume forage, it may not be able to get rid of the gas produced, because this soft forage does not provide the necessary stimulus to cause belching. It is thought that grasses do not cause bloat because the leaves and stems are more irritating or stimulating to the nerves, thus resulting in belching.

Another theory concerning the effect of coarse feed is that it greatly increases the secretion of saliva, and this prevents the formation of froth in the rumen. Whatever the reason is, the consumption of coarse, scratchy feed seems to aid in preventing bloat.

Keeping dairy cows off dangerous legume pasture at night and instead feeding them plenty of coarse but palatable hay, like Sudan hay, or very coarse alfalfa, has prevented bloating. Feeding them straw at night was not effective, because the cows ate but little of it and were ravenous for the legume forage in the morning. Allowing the stock to have access to palatable hay in a rack or stack while on pasture will also help prevent trouble. In a large pasture the hay rack should be in the center, so the cattle have convenient access to it.

Another method is to keep cows on good grass pasture at night and graze them on the legume pasture only during the daytime. Some have advocated keeping cows on the legume pasture day and night, when they are once accustomed to it. However, there is then danger that bloat may occur during the night, and the animal may die before the trouble is noticed.

In some New Zealand trials bloat on legume-grass dairy pastures has been largely prevented by strip grazing, or rationed grazing, in which the cattle are confined by electric fences to a new strip of pasture each day. (377) They then eat all the forage uniformly—grass and legumes, leaves and stems—instead of grazing selectively and consuming too much of the legume tops and leaves.

Sometimes cattle or sheep bloat when fed alfalfa hay along with a heavy allowance of such grain as barley or wheat. The trouble is more apt to occur with very fine, leafy hay than when the hay is coarser and stemmier. Such bloating, which is usually of the frothy type, can generally be prevented by feeding corn silage, beet-top silage, cottonseed hulls, or other palatable nonlegume roughage, in addition to the alfalfa hay, or else by mixing corn, oats, or dried beet pulp with the barley or wheat. Bloat rarely occurs with cattle or sheep fed only alfalfa hay, without grain.

In recent Mississippi trials bloat of cattle on legume pasture was greatly reduced when a mixture of 800 milligrams of procaine penicillin per pound of salt was supplied in a covered salt box, instead of ordinary salt. No other salt was fed.

In severe cases of bloat, prompt treatment is necessary. Sometimes vigorous massaging of the left flank may help, or tying a wooden bit in the mouth may give relief, as the animal will champ its jaws in an effort to get rid of the bit, and this seems to stimulate belching. Some recommend placing the animal with its front feet elevated. Administering a dose of 2 to 4 ounces of turpentine to cattle suffering from bloat often gives relief. Care is necessary to avoid getting the turpentine into the trachea, or windpipe. In the more severe cases, it may be necessary to get rid of the gas by means of a stomach tube, or to tap the rumen and release the gas by means of a trocar, or even with a clean knife, if a trocar is not available.

II. Use of Nutrients in the Body

50. Metabolism.—Through painstaking research, chemists and physiologists have been able to gain much information on the various steps in the digestion of food. When the nutrients

leave the digestive tract and enter the body, the difficulties of learning what becomes of them are much greater. Though many of the changes that occur in the body have been revealed, only a little of a definite nature is yet known concerning other processes.

Metabolism is the term used for all the changes which take place in the nutrients after they are absorbed from the digestive tract. These changes include not only the building-up processes in which the absorbed nutrients are used in the formation or repair of body tissues, but also the breaking-down processes in which nutrients are oxidized for the production of heat and work.

51. Distribution and use of absorbed nutrients.—We have seen that all the digested nutrients are absorbed chiefly by the villi of the small intestine and finally enter the blood circulation. The blood, containing these nutrients, reaches the capillaries in all the body tissues. Here the nutrients can pass through the capillary walls into the lymph that surrounds the body cells. The nutrients then enter the cells, providing nourishment and energy for the various life processes.

The nutrients thus brought to all parts of the body may be used for several purposes. First come the maintenance needs for the preservation of life. These are discussed in detail in Chapter VIII. The daily break-down of the protein tissues must be replaced by the amino acids resulting from the digestion of the protein of the food. Also, some of the nutrients must be oxidized to provide heat for maintaining the body temperature and to furnish energy for the various necessary movements of the body.

If more nutrients are supplied than are needed merely to maintain the body, the following uses can be made of the excess nutrients: (1) They can be made into new body tissue, as in the case of growing and fattening animals; (2) they can be used in the development of the fetus in the case of a pregnant female, and for the formation of eggs in the case of birds; (3) they can be changed into milk, as in the case of dairy cows; or (4) they can be used for the production of muscular work, as in the case of work horses and mules. The uses of nutrients for each of these purposes are discussed in later chapters.

The sugars serve as sources of heat and muscular energy and also as the chief source of the lactose (milk sugar)

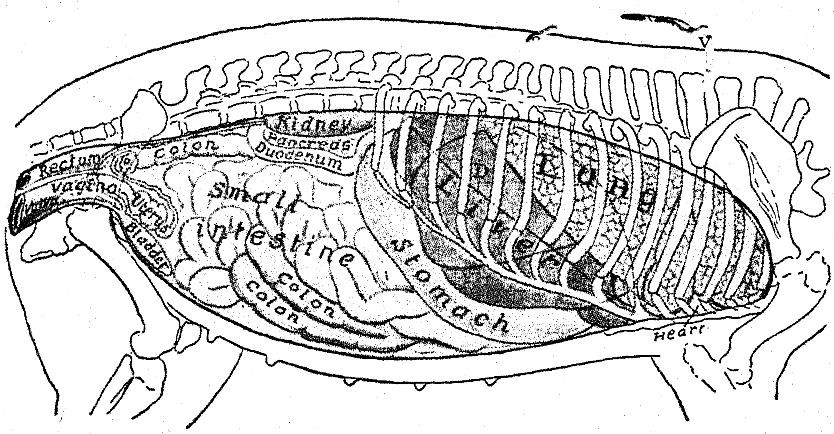


DIAGRAM OF DIGESTIVE SYSTEM OF PIG; RIGHT SIDE

The pancreas and duodenum are not in contact with the flank, as would be inferred from this figure, but are situated nearer the center of the body, and if viewed from the right side, would be covered by the small intestine. (From Sisson, "Anatomy of the Domestic Animals.")

in milk. They can also be changed into body fats. The organic acids produced in the rumen digestion of ruminants can be used somewhat like the sugars. The fats, like the sugars, can furnish heat and energy, and can form body fat and the fat in milk.

If there is a greater supply of amino acids than is needed for body repair or for the building of new protein tissues, the nitrogen (in the form of ammonia) is split off in the liver from the amino acid molecule. The nitrogen is entirely wasted in this process, which is called deaminization, for it is converted into compounds which are excreted in the urine. Also, there is some loss of energy in the nitrogenous waste products. The non-nitrogenous parts of the amino acids that remain can, however, be used in the body for the same purposes as the sugars.

Even when the supply of protein in the food is scanty, a considerable wastage of protein unavoidably occurs for some unknown reason, through the deaminization of amino acids in the liver. Therefore, as is explained in Chapter VIII, more protein must be supplied in maintenance rations than is theoretically needed to replace the daily breakdown of the protein tissues of the body.

It has been previously pointed out that most of the changes in the digestion of food are brought about by enzymes. It is now believed that most other body processes, both the building-up processes and the tearing-down processes, are likewise brought about through enzyme action.

52. Oxidation of nutrients in the body.—Nutrients are constantly being oxidized in the body tissues to provide the energy for all muscular movements and also to furnish heat to maintain the body temperature. These oxidations are produced in the following manner:

In the lungs oxygen is absorbed from the air by the hemoglobin (the red-colored compound in the red blood cells) and is held in loose combination with it. The blood, carrying this oxygen, passes back to the heart and is then carried by the arteries to all parts of the body. In the capillaries the blood gives up oxygen to the body cells.

Many investigations have been conducted by physiologists and biochemists to determine, if possible, the exact changes that take place in the oxidation of the various nutrients in the body. Considerable interesting information has been gained, and various theories have been advanced concerning the steps that occur. For a discussion of these theories the reader is referred to texts on physiology or biochemistry.

For our purposes it is sufficient to state that by intricate processes the carbohydrates, fats, and other nutrients can be oxidized in the tissues to produce energy and heat. In these changes the carbohydrates and fats are eventually oxidized completely to carbon dioxide and water. The carbon dioxide is absorbed by the blood and carried in the veins to the heart, and thence to the lungs. Here it passes off into the air in the lungs and is exhaled, the blood then becoming again charged with oxygen before it flows back to the various parts of the body.

53. Functions of the liver.—The liver, which is the largest gland in the body and which secretes bile, has several important functions. The functions which have already been mentioned in this chapter are: The regulation of the glucose content of the blood through the formation of glycogen; the important part bile has in the digestion and absorption of fat; and the deaminization of amino acids, in which nitrogen is split off in the form of ammonia. The liver also stores vitamin A. It synthesizes fatty acids from carbohydrates or protein, and is important in the use of fat for fuel in the body. The liver protects the body against various poisonous substances, formed in the digestive tract through putrefaction, by changing them into non-poisonous compounds. Among its other functions, it is an important agent in the destruction of worn-out blood cells, and in the formation of blood proteins.

Besides its part in fat digestion, bile probably accelerates the action of the amylase of the pancreatic juice. It also

has a moderately laxative effect and aids in the passage of food through the intestine.

54. Hormones, or internal secretions.—Physiologists have found by extensive investigations that many of the body processes are controlled and regulated by substances called *hormones,* or *internal secretions.* These are produced by the glands of internal secretion, also called the endocrine glands, or the ductless glands.

The secretions of these glands are discharged directly into the blood, or perhaps indirectly by way of the lymph, and are not poured out through a duct, as in the case of the bile and the pancreatic juice. This is the reason why they are referred to as the ductless glands. The hormones are carried in the blood to the parts of the body where they perform their functions. The relations of hormones to such body processes as reproduction, the development of the udder, and the secretion and "let down" of milk are explained in later chapters. Among the important hormones are the following:

Insulin, a hormone produced by the pancreas, is necessary for proper carbohydrate metabolism in the body. Without an adequate supply of this hormone, the ability of the body tissues to oxidize and utilize glucose is decreased. Also, the rate at which glucose is formed from glycogen and from fats and proteins is increased. As a result, the level of glucose in the blood rises, glucose is excreted in the urine, and there are other injurious effects.

The discovery in 1921 of the importance of insulin in carbohydrate metabolism has been of untold benefit to persons suffering from diabetes. In diabetes there is a lack of insulin, with resulting serious consequences. Hypodermic injections of a carefully purified and standardized solution of insulin now bring relief to a patient affected with the disease.

A hormone, called *secretin,* which is produced by the lining of the small intestine, is important in the digestion of food. As soon as the acid, partly-digested food passes from the stomach into the small intestine, the acidity causes the mucous membrane of the small intestine to form secretin. This is absorbed by the blood and carried to the pancreas, where it causes this gland to pour out the pancreatic juice just when it is needed.

The *thyroid gland,* located in the neck, produces *thyroxine,* a hormone that regulates the rate of body metabolism. This hormone has been separated in pure form and found to be an iodine-containing amino acid. As is pointed out in Chapter VI, when there is insufficient iodine in the food the gland enlarges in a desperate effort to manufacture enough thyroxine, and the disease called goiter results.

Thyroprotein, or iodinated casein, which contains thyroxine and other compounds that have a similar effect on body metabolism, is now made commercially by treating milk casein under carefully controlled conditions. Information is given in the chapters of Part III on the use of this product for dairy cows and other classes of stock.

The *parathyroid glands* are very small glands, usually located close to the thyroid gland or imbedded in it. They secrete a hormone which controls the concentration of calcium in the blood. If for any reason the calcium content of the blood is too low, convulsions or paralysis may be caused, as in milk fever of dairy cows.

The *pituitary,* or hypophysis, a small gland at the base of the brain, has several essential functions. Hormones produced by the pituitary seem to stimulate the other glands of internal secretion and thus regulate many body processes. The pituitary is therefore often called the master gland of the body. A hormone produced by the anterior, or forward, part of the gland controls the growth and development of animals and therefore determines the mature body size. If the gland is too active, the body may be of giant size, and on the other hand an insufficiency of the hormone will dwarf the size.

This part of the gland likewise produces certain sex hormones and a hor-

mone that is necessary to start milk secretion in the female. (298) It is also believed to be concerned with the activity of the thyroid gland and other glands. The posterior, or rear, portion of the gland secretes a hormone that stimulates the contraction of the smooth, or involuntary, muscles. This hormone causes the "let down" of milk in dairy cows. (1093)

The *adrenal glands,* or suprarenals, which are two small glands located close to the kidneys, produce various hormones. One of these helps to keep the glucose content of the blood constant by regulating the rate at which glycogen is changed into glucose. Another hormone produced by the adrenal glands seems to be necessary for lactation; a third, for controlling the concentration of water and mineral salts in the blood and tissues; and a fourth for increasing blood pressure in times of emergency.

The *sex glands* secrete hormones that have important functions. Thus, as is explained in Chapter X, hormones produced by the ovaries are necessary for the growth and development of the mammary glands.

Synthetic compounds have been made that have some of the properties of natural sex hormones. Recently, there has been much interest in the use of certain of these compounds in the commercial fattening of poultry, beef cattle, and sheep. The use for this purpose of diethylstilbestrol (commonly called stilbestrol) and of other hormones is discussed in the chapters dealing with these classes of stock.

Recent investigations have shown that certain hormones naturally present in some feeds may affect livestock production.[8] These studies have indicated that the favorable effects of young, actively-growing pasture on milk production and growth may be partly due to hormones the plants contain. At late stages of growth such effects were not found. In other experiments certain lots of alfalfa hay, clover hay, and soybean oil meal had a favorable hormone-like effect.

In one case a hormone naturally present in plants has a very injurious effect. Serious breeding troubles have been caused in Australia in sheep grazing on pasture containing chiefly subterranean clover, with little grass in the mixture. (483)

55. Disposal of body waste.—The undigested food and certain waste products accumulate in the rear part of the large intestine in the form of a more or less solid residue. This is expelled as the feces. The feces of farm animals consist chiefly of undigested food that has never really been within the body proper. This undigested food is mostly cellulose and lignin. Also, a portion of the other nutrients usually escapes digestion. This may be due to insufficient chewing of such food as seeds, or because some nutrients are protected from the digestive juices through being enclosed in resistant cell walls.

In addition to undigested food the feces also contain residues from the digestive fluids, waste mineral matter, worn-out cells from the intestinal lining, mucus, and bacteria. They may also contain such foreign matter as dirt consumed along with the food. In the case of man and of such animals as dogs and cats, the greater part of the feces consists of excretory products, rather than undigested food.

Nearly all of the nitrogenous waste, resulting from the break-down of protein material in the body, is excreted in the urine through the kidneys, though a trace is given off in the sweat and a more appreciable amount in the feces. In mammals this waste chiefly takes the form of urea, while in birds it is excreted chiefly as uric acid.

A great variety of other end-products of metabolism are likewise eliminated by the kidneys through the urine. Some of the mineral matter is excreted in the urine. However, calcium, magnesium, iron, and phosphorus are voided chiefly in the feces. Small amounts of most of the substances eliminated in the urine are also excreted by the skin through the sweat glands.

A large amount of carbon dioxide is formed in the oxidation of the nutri-

ents within the body for the production of heat and energy. Most of this passes into the capillaries and is carried in the blood by the veins to the lungs, where it is eliminated in breathing. A portion, however, escapes by way of the skin. Some of the methane produced by fermentations in the stomach of herbivora is absorbed into the blood and thrown out by the lungs.

56. Importance of quiet, kindness, and regularity.—Farm animals are creatures of habit, and when once accustomed to a certain routine, they show unrest at any decided change. The stable or feed lot should therefore be free from disturbance. The good stockman is kind to his animals and they trust him, but stock may fear a rough or careless person.

Feed and water should be supplied regularly, and large changes should be made gradually. Animals know when meal time has come, and they fret if feeding is delayed. Investigations with human beings have shown that worry and excitement cause a definite decrease in the completeness with which foods are digested. It is reasonable to believe that the same is true in the case of farm animals. At least, there is no question but that unusual excitement may seriously cut down the milk production of dairy cows and reduce the gains of fattening stock.

57. Importance of palatability.—The palatability of feeds is a factor of no small importance in the efficient feeding of stock. It seems possible that well-liked feeds are digested somewhat better than those which are equally nutritious, but less palatable.

From an entirely different standpoint, palatability is of great importance in feeding animals for large production. Unless the ration is palatable, dairy cows or fattening stock will not eat enough feed to permit them to produce milk or meat economically. Feeds which are unpalatable should therefore be used chiefly for stock not being fed for production. For example, idle horses can be wintered largely on straw or on hay of rather poor quality. If a limited amount of unpalatable feed is mixed with some well-liked ingredient, stock will often eat the entire mixture readily.

Familiarity and habit are important factors concerned with the palatability of feeds. Not infrequently, when corn silage is first placed before cows, after sniffing it they will let it alone for a time. They then usually begin nibbling at it, and later eat it with great relish. In such cases, food that at first seems unpalatable finally becomes palatable. Sometimes animals which are used to yellow corn will at first refuse white corn or vice versa. If they are accustomed to whole grain, it may take them a little time to become used to ground grain.

Sometimes the failure of animals to continue to eat a normal amount of feed may indicate a serious nutritive deficiency. For example, if thrifty pigs are fed a ration made up of palatable feeds, but which is deficient in vitamin A or in certain minerals, they may eat normal amounts of food for a time and make satisfactory gains. Then, when the body reserves of the lacking nutrient are exhausted, they will usually consume much less feed, due to an impairment of their health and a consequent lack of appetite. Provided that the deficiency is not continued so long that the pigs are injured permanently, they will usually recover their appetites, if some feed is added which supplies the nutritive lack and makes the ration complete.

Usually feeds that are palatable are safe and nutritious. However, in rare instances this may not be true. For example, sorghum which has been stunted by drouth may contain sufficient prussic acid to kill stock in a few minutes, and yet it will be palatable and will be consumed with eagerness. However, stock generally avoid poisonous plants instinctively and eat them only when impelled by hunger.

QUESTIONS

1. Define *digestion*. What is the nature of the changes produced in food during digestion?
2. Define *enzymes*. Describe a typical enzyme action.

3. Describe the digestive tract of cattle and compare it with that of pigs and of horses.
4. State the essential facts concerning the circulation of the blood; of the lymph.
5. What are the villi of the small intestine and what is their function?
6. Of what importance is thorough mastication of the food?
7. Describe briefly the process of rumination.
8. Describe the digestion and absorption of carbohydrates in non-ruminants. State the enzymes or agents concerned, the place where digestion takes place, the substances acted on, and the products formed.
9. Discuss the formation and function of glycogen.
10. Describe the digestion of cellulose and pentosans by ruminants and by horses. Follow the same outline as for carbohydrates, above.
11. What deficiences in the food may decrease digestion in the rumen?
12. Describe the digestion and absorption of protein, following the same outline.
13. Describe the digestion and absorption of fats, following the same outline.
14. What can be said concerning the digestion of minerals?
15. Summarize the information on the cause of bloat and ways in which it may be prevented.
16. Define *metabolism.*
17. How are the absorbed nutrients distributed to the body tissues?
18. What functions are performed by the absorbed sugars; the fats; the amino acids?
19. Describe the oxidation of nutrients in the body.
20. What are the functions of the liver?
21. Give an illustration of the action of a hormone.
22. Describe the disposal of the various waste products of the body.
23. Discuss the importance of quiet, kindness, and regularity in stock feeding.
24. Of what importance is the palatability of feeds?

REFERENCES

1. Marshall, Dix Arnold, Becker, and Wing, Fla. Rpts. 1952, 1953; Becker, Dix Arnold, Marshall, and Wing, Fla., Jour. Dairy Sci., 35, 1952, pp. 504–505; Kesler, Ronning, and Knodt, Penn., Jour. Anim. Sci., 10, 1951, pp. 969–974.
2. Fuller, N.H. Tech. Bul. 35.
3. Schalk and Amadon, N.D. Bul. 216; Nevens, Ill., Jour. Agr. Res., 36, 1928, pp. 777–794; Kick, Gerlaugh, Schalk, and Silver, Ohio, Jour. Agr. Res., 55, 1937, pp. 587–597.
4. Nevens, Ill., Jour. Agr. Res., 36, 1928, pp. 777–794; Schalk and Amadon, N.D. Bul. 216; Kick, Gerlaugh, Schalk, and Silver, Ohio, Jour. Agr. Res., 55, 1937, pp. 587–597.
5. Dukes, The Physiology of Domestic Animals, 7th ed., 1955, p. 49.
6. For a review on digestion in the rumen, see Doetsch and Robinson, Md., Jour. Dairy Sci., 36, 1953, pp. 115–142. For later reports see: Stallcup, Cason, and Walker, Ark., Jour. Dairy Sci., 38, 1955, p. 625; Hall, Cheng, Hale, and Burroughs, Iowa, Jour. Anim. Sci., 14, 1955, p. 1205; Hubbert et al., Iowa, Jour. Anim. Sci., 14, 1955, p. 1209; Radisson, Bartley, Fountaine, and Atkeson, Kan., Jour. Anim. Sci., 12, 1953, p. 929; Lassiter et al., Ky., Jour. Anim. Sci., 14, 1955, pp. 1213–1214; Woods, Thompson, and Grainger, Ky., Jour. Anim. Sci., 14, 1955, pp. 1225–1226; Gibbons, Doetsch, and Shaw, Md., Jour. Dairy Sci., 38, 1955, pp. 1147–1154; Agrawala, Duncan, and Huffman, Mich., Jour. Nutr., 49, 1953, pp. 29–39; Agrawala, Huffman, Luecke, and Duncan, Mich., Jour. Nutr., 49, 1953, pp. 631–638; Emery, Smith, and Huffman, Mich., Jour. Anim. Sci., 14, 1955, p. 1201; Brooks et al., Mo., Jour. Anim. Sci., 13, 1954, pp. 758–764; Garner, Muhrer, and Pfander, Mo., Jour. Anim. Sci., 13, 1954, p. 983; Wasserman, Seeley, and Loosli, N.Y., Jour. Dairy Sci., 37, 1954, p. 663; Waldo and Schultz, N.Y., Jour. Dairy Sci., 38, 1955, p. 605; Cason, Mochrie, and Thomas, N.C., Jour. Anim. Sci., 14, 1955, p. 1236; Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732; Bentley, Johnson, Vanecko, and Hunt, Ohio, Jour. Anim. Sci., 13, 1954, pp. 581–593; Hunt, Bentley, Hershberger, and Cline, Ohio, Jour. Anim. Sci., 13, 1954, pp. 570–580; Bentley et al., Ohio, Jour. Anim. Sci., 13, 1954, p. 1015; 14, 1955, pp. 1194–1195; Tillman et al., Okla., Jour. Anim. Sci., 13, 1954, pp. 417–731; Hollis, Chappel, MacVicar, and Whitehair, Okla., Jour. Anim. Sci., 13, 1954, pp. 732–738; Fontenot, Gallup, and Nelson, Jour. Anim. Sci., 13, 1954, pp. 982–983; Embry, DuBose, Gastler, and Olson, S.D., Jour. Anim. Sci., 14, 1954, p. 1201; Nichols, Moore, and Dillon, Wis., Jour. Anim. Sci., 14, 1955, pp. 276–278; Bryant and Burkey, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 205–224, 588–589; Huhtanen, Saunders, and Gall, Jour. Dairy Sci., 37, 1954, pp. 328–335; Balch, Kelly, and Heim, England, British Jour. Nutr., 5, 1951, pp. 207–216; Pfander and Phillipson, Scotland, Jour. Anim. Sci., 11, 1952, pp. 798–799; Heald, Scotland, British Jour. Nutr., 7, 1953, pp. 124–130; Phillipson, Scotland, Biochem. Jour., 54, 1953, p. 3.
7. For reviews on bloat in ruminants, see Cole, Huffman, Kleiber, and Schalk, Jour. Anim. Sci., 4, 1954, pp. 183–236, reprinted in Nat. Res. Council, Reprint and Cir. Series, No. 124; and Dougherty, N.Y., Jour. Amer. Vet. Med. Assoc., 122, 1953, pp. 345–352. For later reports, see Colvin, Cupps, and Thompson, Cal., Jour., Dairy Sci., 38, 1955, p. 606; Parsons, Whitehair, and Neumann, Ill., Jour. Anim. Sci., 12, 1953, pp. 926–927; Shaw and Jackson, Ind., Jour. Anim. Sci., 14, 1955, p. 1255; Blake, Jacobson, and Allen, Iowa, Jour. Dairy Sci., 38, 1955, p. 606; Derrickson, Thompson, and Grainger, Ky., Jour. Anim. Sci., 14, 1955; p. 1244; Jacobson and Lindahl, Md. and

U.S.D.A., Jour. Dairy Sci., 38, 1955, p. 606; Smith, Brunner, Huffman, and Duncan, Mich., Jour. Anim. Sci., 12, 1953, p. 932; Barrentine, Miss. Farm Res., 17, 1954, No. 3; Barrentine, Shawver, and Williams, Miss., Jour. Anim. Sci., 13, 1954, p. 1006; Dougherty, Meredith, and Barrett, N.Y., Amer. Jour. Vet. Res., 16, 1955, pp. 79–90; Nichols, Wis. Bul. 510; Nichols, Moore, and Dillon, Wis., Jour. Anim. Sci., 12, 1953, p. 952; Nichols, Moore, and Dillon, Wis., Jour. Anim. Sci., 14, 1955, pp. 276–278; Lindahl, Cook, Davis, and Maclay, U.S.D.A., Science, 119, 1954, pp. 157–158.

8. For a review on hormones in livestock production, see Sykes, Andrews, Hill, Lorenz, Thomas, and Winchester, National Research Council Publication 266, 1953. Later references are given under the various classes of stock.

CHAPTER III

MEASURING THE USEFULNESS OF FEEDS

I. Determining the Relative Values of Feeds

58. Methods of measuring the values of feeds.—In computing balanced rations for livestock we must know the amounts of nutrients furnished by the various available feeds. Also, in order to plan an efficient cropping system on a stock farm, we must have accurate information concerning the actual feeding value of the various crops that can be grown.

The simplest method of measuring the value of any feed is to determine the amounts of digestible nutrients that it supplies. This method is explained first in this chapter. A method that is theoretically more accurate, but which is much more complicated and expensive, is to determine the amount of net energy supplied by the feed. This method is discussed later. (68–73)

Neither of these chemical methods takes into consideration all the factors which determine the true value of any feed for a particular class of livestock. The only way in which this can be done is to conduct actual feeding experiments under practical conditions with this class of stock. In these tests the relative value of the particular feed can be found, in comparison with that of a standard feeding stuff.

The American experiment stations have conducted many hundreds of such feeding experiments to determine the actual values of the most common feeds and of different rations for the various classes of farm animals. It is of great financial importance to stock farmers to have definite information readily available concerning the value of the various feeds for each class of animals. The author has therefore spent much time in compiling the results of these numerous experiments in order to draw reliable conclusions concerning the relative values of the different feeds.

A single experiment, no matter how carefully planned and conducted, does not give reliable information about the relative value of different feeds or rations. This is because various lots of any feed may differ appreciably in composition, as is emphasized in Chapter IV. Also, individual animals differ in productive capacity. To draw safe conclusions concerning the value of any feed, it is therefore necessary to study and analyze carefully all the available information.

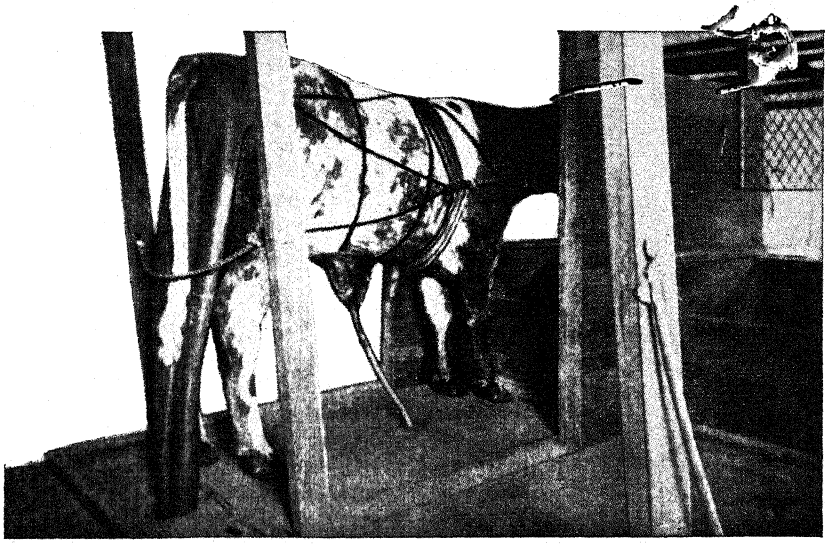
In Part II of this volume detailed information is given about the usefulness and value of all of the important feeds for each of the classes of livestock. Wherever data are available, definite statements are made concerning the relative value of each feed, based on the results of actual feeding experiments that have been conducted under practical conditions.

59. Value of a feed may differ for various animals.—In the discussions of the various feeds in Part II, it will be noted that in several instances the actual value of a particular feed for two classes of stock may differ considerably. For example, a ton of good corn silage is worth 33 to 40 per cent as much as a ton of legume or mixed hay for dairy cows. For fattening cattle and lambs silage has a higher value, being worth fully one-half as much per ton as good hay.

Similarly, ground barley is about equal to ground corn for dairy cows, but for swine or for fattening cattle or lambs its relative value is appreciably lower. Also, barley injured by the scab disease is satisfactory for cattle and sheep, but it is unsuited to horses and pigs.

Another interesting example is the

fact that cottonseed meal of the usual kind can be fed safely to cattle in large amounts, if plenty of vitamins and minerals are provided. On the other hand, pigs should be fed only limited amounts of such cottonseed meal, or disastrous results may follow. Again, uncooked field beans give satisfactory results when forming not too large a part of the ration for dairy cows, beef cattle, and sheep, but pigs do poorly on beans unless they are cooked.



A STEER IN A DIGESTION STALL

In digestion trials the feces may be collected in several ways. A common method is by means of the harness and rubber duct here shown. When it is merely desired to determine the digestibility of a feed, the urine need not be collected, as is being done in this trial. (From Pennsylvania Station.)

Such differences as these may not be shown at all by determinations of the amounts of digestible nutrients or of net energy in a feed. They can be revealed only by actual experiments with the particular kind of animal in question. These examples show that in order to feed any class of stock most efficiently one must not only consider the amounts of nutrients supplied by various feeds, but also must know the results that are actually produced when these feeds are fed to that class of stock.

60. Digestion experiments and digestion coefficients.—The digestibility of a particular feed for any class of stock is determined by means of digestion experiments with that kind of animal. The chemist first finds by analysis the percentage of each nutrient the feed contains. The animal is then fed weighed quantities of the feed for a preliminary period of a few days, so that all residues of former feed may pass out of the digestive tract.

During the digestion experiment the same amount of the feed is given to the animal each day. The feces are carefully collected and weighed, and samples are analyzed. The differences between the amount of each nutrient fed daily and the amount found in the feces is the amount of the nutrient that is digested. From this information, there is computed the percentage of each nutrient which is digested from the feed.

The percentage of each nutrient digested in a feed is called the *digestion coefficient* for that nutrient in the feed.

To show how the digestibility of a feed is determined, let us suppose that during a 10-day digestion experiment, a

cow was fed 20 lbs. of clover hay each day, containing 13.26 per cent of protein. This amount of the hay would therefore contain 2.65 lbs. of protein. During the experiment the cow excreted, on the average, 47.3 lbs. of feces daily, which contained 2.32 per cent protein, or a total of 1.10 lbs. of protein.

Subtracting 1.10 lbs. (the amount of protein in the feces) from 2.65 lbs. (the amount of protein in the 20 lbs. of hay fed daily), we find that 1.55 lbs. of protein were digested. Next, we divide 1.55 lbs. by 2.65 lbs. and multiply the quotient by 100, to find the digestion coefficient for protein in the hay, or the percentage of the protein digested. This is 58.5 per cent. The digestion coefficients for the fat, fiber, and nitrogen-free extract in the feed are found in a similar manner.

In the case of feeds for which no digestibility data are available, Schneider and associates have developed formulas for estimating digestion coefficients of various classes of feeds from the chemical composition of the particular feed.[1]

61. Determining digestibility by difference.—Some feeds cannot be fed alone, as was done in this experiment. Thus, horses and ruminants are not fed concentrates alone, without hay or other roughage. Again, while pigs may be fed on grain only, such feeds as tankage and linseed meal are too rich in protein to be fed alone. The digestibility of such feeds must therefore be found by difference, instead of directly.

For example, in an experiment to determine the digestibility of oats for sheep, a sheep is first fed hay for several days, and the digestibility of the hay found. Then oats are added to the ration, and the total amounts of nutrients are determined that are digested from the combination of oats and hay. The amounts of digestible nutrients coming from the hay are then subtracted from the total, leaving the amounts which are assumed to be digested from the oats.

62. Digestion coefficients in Appendix Table I.—Individual animals of the same species vary somewhat in their ability to digest any given feed. It is therefore essential, in computing the digestible nutrients in feeds as a guide for stock feeding, to use average digestion coefficients that are based on all representative digestion trials which have been conducted.

The author has made for this edition of *Feeds and Feeding* a new compilation of the digestion coefficients for the various feeds that have been determined in the many trials by the American experiment stations. The average digestion coefficients are presented on the right-hand pages of Appendix Table I.

In the case of feeds for which American data are not available or are very limited, digestion coefficients obtained in experiments in other countries have been included. Especially useful in such cases has been the extensive compilation made by Schneider of digestion coefficients obtained in experiments in various countries.[2]

It will be noted, on inspecting the digestion coefficients for various feeds given in Appendix Table I, that feeds which contain but little fiber, such as corn and wheat, are highly digestible. This is because the cell walls are thin and are easily penetrated by the digestive juices. The more fiber a feed contains, generally the thicker and more resistant are the cell walls, and consequently the lower is the digestibility of the feed. Thus, oats and bran are somewhat less digestible than corn and wheat, and the roughages have considerably lower digestion coefficients.

It is pointed out in Chapter XIII that young pasture forage is much more digestible than the same plants at later stages of growth. (358) The difference is especially great when the plants become mature and is still greater if the mature plants are weathered by exposure. This difference in digestibility as plants grow older is due to a considerable extent to increase in lignin, which is nearly indigestible, even by ruminants.

The nitrogen-free extract in the cereal grains and in most other high-grade concentrates is considerably more digestible than the fiber. On the other

hand, in such roughages as the grasses and corn or sorghum forage, the fiber may be more digestible than the nitrogen-free extract. This is probably because these roughages have considerable lignin, and much of the lignin, though mostly indigestible, is unfortunately included in the nitrogen-free extract in the usual method of feed analysis. Information about the digestibility of various feeds is given in the detailed discussions about the individual feeds in Part II.

As has been explained in the previous chapter, cattle and sheep digest feeds high in fiber more completely than do horses and swine. In spite of this difference, the digestion coefficients obtained in tests with cattle and sheep are commonly used in computing rations for horses and swine, because only a few digestion trials have been carried on with the latter animals. However, no error of importance is involved in this, for the recommendations in modern feeding standards take this fact into consideration.

63. Digestible protein; total digestible nutrients.—To find the percentages of digestible nutrients in any feeding stuff, the percentage of each nutrient is multipled by the digestion coefficient for that nutrient. For example, dent corn of U.S. Grade No. 1 contains 8.9 per cent of protein (See Appendix Table I), of which 77 per cent is digestible. Therefore the percentage of digestible protein is 6.9. In this manner the data have been computed which are given in the second and third columns of figures in Appendix Table I.

Since protein has special functions in the body which can be performed by none of the other nutrients, the percentages of *digestible protein* are shown separately in the second column. Next are given the percentages of *total digestible nutrients* in the various feeds.

The *total digestible nutrients* is the sum of all the digestible organic nutrients—protein, fiber, nitrogen-free extract, and fat (the latter being multiplied by 2.25, because its energy value for animals is approximately 2.25 times that of protein or carbohydrates). The abbreviation T.D.N. is often used for *total digestible nutrients.*

The percentages of total digestible nutrients therefore represent the approximate heat or energy value of the feed. The digestible protein is included in this total, since protein serves as a source of heat and energy when more is provided than is required to meet the protein needs of the body.

An inspection of Appendix Table I will show the wide differences there are in the amounts of digestible protein and of total digestible nutrients in the various feeds. The cereal grains and other seeds are rich in total digestible nutrients, as are also the by-product feeds that are low in fiber. At a hay stage, grasses and legumes have much smaller amounts of total digestible nutrients than the grains and other concentrates, and the straws are especially low.

On the dry basis, young grass or legume pasture may supply nearly as much total digestible nutrients as some concentrates. For example, young mixed grass and legume pasture from a fertile, well-grazed field may contain 70 per cent total digestible nutrients in the dry matter, in comparison with 80 per cent or more in the dry matter of a good concentrate mixture.

A few feeds, such as flaxseed, which are unusually rich in fat, supply more than 100 lbs. of total digestible nutrients per 100 lbs. of the feed. This is due to the fact that digestible fat is multiplied by 2.25 when it is included in the sum, "total digestible nutrients." For example, the high figure of 108.3 per cent of total digestible nutrients for flaxseed means that 100 lbs. of flaxseed furnish as much heat or energy as would be supplied by 108.3 lbs. of digestible starch.

64. Other methods; digestible energy.—Methods have been recently proposed for reducing the chemical determinations needed to find in a digestion trial the amount of total digestible nutrients in a feed or ration. One method, proposed by Lofgreen,[3] is based on determining only the water, mineral matter, and fat in the feed, and the water and

mineral matter in the feces. The digestibility of the total organic matter is first calculated, and this is then multiplied by a factor based on the percentage of fat in the feed, to give the estimated percentage of total digestible nutrients. This method gave results which agreed well with those determined by the standard method. A somewhat similar method has been proposed by Reid.[4]

Instead of using total digestible nutrients in valuing feeds and computing rations, *digestible energy* can be used.[5] This can be determined by burning samples of the feed and of the feces in a bomb calorimeter. The method is not in general use.

Total digestible nutrients can be calculated from the content of digestible energy, and digestible energy from the content of total digestible nutrients. The approximate energy value of 1.0 lb. of total digestible nutrients has commonly been assumed to be 1,814 Calories. However, according to studies of Schneider and associates of the Washington Station, the value of 1,987 Calories per pound, or 4.38 Calories per gram, of total digestible nutrients is more accurate.[6]

65. Nutritive ratio.—As protein serves special uses in the body, in discussions of feeding stuffs and rations the term *nutritive ratio* is employed to show the proportion of digestible protein.

By *nutritive ratio* is meant the ratio, or proportion, between the digestible protein and the digestible non-nitrogenous nutrients (including fat multiplied by 2.25).

When the percentage of total digestible nutrients is given, as in Appendix Table I, the nutritive ratio is computed as follows: The percentage of *digestible protein* is subtracted from the percentage of *total digestible nutrients* to obtain the percentage of digestible *non-nitrogenous nutrients.* This remainder is divided by the *digestible protein,* the quotient being the second term of the ratio.

The manner of computing the nutritive ratio of Grade No. 1 dent corn is as follows:

Total dig. nutrients Per cent		Dig. protein Per cent		Dig. non-nitrogenous nutrients Per cent
81.9	—	6.9	=	75.0

Dig. non-nitrogenous nutrients Per cent		Dig. protein Per cent		Second factor of nutritive ratio
75.0	÷	6.9	=	10.9

Nutritive ratios are expressed with the colon. The nutritive ratio of dent corn is therefore 1 : 10.9 (read as 1 to 10.9). This means that for each pound of digestible protein in corn there are 10.9 lbs. of digestible non-nitrogenous nutrients, including fat multiplied by 2.25.

A feed or ration having much protein in proportion to the non-nitrogenous nutrients is said to have a *narrow nutritive ratio;* if the reverse, it has a *wide nutritive ratio.* Oat straw has the extremely wide nutritive ratio of 1 : 62.9, because of its low content of digestible protein compared with the carbohydrates and fat. Oat grain has the medium one of 1 : 6.5, and protein-rich soybean oil meal the very narrow ratio of 1 : 1.1, the digestible non-nitrogenous nutrients being less than twice the digestible protein.

Another method of computing the nutritive ratio, which is even simpler than the preceding, is as follows: Divide the percentage of *total digestible nutrients* by the percentage of *digestible protein,* and subtract 1.0 from the quotient. The result will be the second term of the nutritive ratio. For example, the nutritive ratio of Grade No. 1 dent corn is found as follows:

Total dig. nutrients Per cent		Dig. protein Per cent		
81.9	÷	6.9	=	11.9

				Second factor of nutritive ratio
11.9	—	1.0	=	10.9

66. Determining digestibility by other methods.—There has been much interest recently among animal nutrition scientists in methods of reducing the cost and time required in digestion experiments by the use of methods in which the feces are not collected and weighed but are merely sampled and analyzed.

One method is to determine the lignin

content of the forage or ration and the lignin content of the feces. In this method it is assumed that lignin is not digested to any appreciable extent, even by ruminants, and that therefore all the lignin in the feed eaten will be in the feces. The digestibility of the various nutrients can then be determined from the percentage of lignin and of the nutrient in the feed and the percentage of each in the feces. Although it has been found that a small percentage of the lignin in some feeds may be digested by a ruminant, an average correction can be made for this.[7]

In some experiments in which the lignin method has been compared with the standard method, the results have agreed well, but in others the lignin method has been less satisfactory.[8]

In another method carefully weighed amounts of chromic oxide, an inert, indigestible compound, are administered to the animal each day, and the amount in the feces determined.[9]

Reid of the New York (Cornell) Station has developed a method of using a naturally occurring plant pigment, or chromogen, in forage plants as an indicator in digestion experiments.[10] This method is based on the fact that this pigment is apparently entirely indigestible and completely recovered in the feces. This method is proving especially useful in determining the digestibility of the forage eaten by animals on pasture.

By combining the use of the chromogen method and the chromic oxide method or by the chromic oxide method alone, the amount of pasturage dry matter eaten daily can be found.[11] In some such studies, a complete collection of the feces voided daily is made by means of a feces bag attached to the animal. The forage consumption can even be estimated approximately by taking samples of the feces at stated times each day, without total collection.

In still another method, the digestibility of forage is estimated from the nitrogen content of the forage and the feces. This method seems to be less reliable than the chromogen method or the chromic oxide method.[12]

A chemical method in which a sample of feed is digested with enzymes in the laboratory gives approximate information on the digestibility of such feeds as meat and fish by-products.[13]

67. Limitations of digestion trials.—The data secured in digestion trials provide the general basis for our knowledge concerning the amounts of digestible nutrients furnished by the many different feeding stuffs. Such data are therefore highly inportant in the science of stock feeding.

Even the net-energy values of feeds, which are discussed later in this chapter, are usually computed from tables of digestible nutrients, such as Appendix Table I of this volume, by applying certain factors to the values for digestible nutrients. However, in using tables of digestion coefficients and digestible nutrients, it is well to bear in mind that the digestibility of a particular sample of a feed may differ appreciably from the average digestibility for that kind of feed. Also, various conditions may affect the digestibility of a feed or ration.

Information is given in the next chapter concerning the effects upon digestibility of such factors as various methods of preparing feeds, the amount of feed eaten, and the proportion of protein and other nutrients in the ration.

Because of the variations in digestibility of different lots of the same kind of feed, some scientists have doubted whether the use of such average data is advisable. However, from a detailed statistical study of the available data, Schneider and associates concluded that applying average digestion coefficients for a given feed to individual lots of that feed is warranted.[14]

The following information concerning the limitations of digestion trials is of scientific interest:

In digestion trials it is commonly assumed that all matter appearing in the feces represents the part of the food which is actually indigestible. This is only approximately correct, for the feces always contain in addition some waste from the body itself, such as unabsorbed residues from the bile and other digestive juices, worn-out cells and mucus from the membranes lining the digestive tract, and waste mineral matter. The feces also include innumerable living and dead bacteria.

In herbivora, such as cattle and horses, which eat much roughage, these products form but a small part of the feces, while in carnivora, such as dogs, they form a considerable portion. All these constituents of the feces are waste products. Therefore, although they do not represent undigested food, it is

entirely correct from a practical standpoint to deduct them, along with the food that is actually undigested, in determining the digestible nutrients which are of use to an animal. These intestinal waste products which are excreted in the feces are a part of the cost of digesting the feed, as they represent the "wear and tear" of the digestive organs.

In nutrition studies, when it is desired to determine how much of the protein of the feed has actually been digested, the feces may be treated with an acid solution of pepsin. This dissolves practically all the protein compounds in the feces except the true undigested food protein.

It has been pointed out in the preceding chapter that in the digestion of cellulose and pentosans by bacteria in the paunch of ruminants and to a less extent in the large intestine of other animals, some of the carbohydrates are broken down into carbon dioxide and methane, gases that have no nutritive value. Yet, due to the method of computing digestible nutrients, these are commonly included in the amount of carbohydrates considered digestible. This does not involve any serious error even with ruminants, and with other classes of stock the discrepancy is usually negligible.

Errors are apt to occur in determining the digestibility of the ether extract, or so-called "fat," for fat is usually present in feeding stuffs in much smaller amounts than protein and carbohydrates. Furthermore, as has been pointed out in Chapter I, ether dissolves not only true fat but also such plant compounds as chlorophyll and waxes. It also dissolves such products in the feces as the bile residues.

The true fats are highly digestible, but the waxes, etc., are of rather low digestibility. Fraps and Rather, on studying the ether extract obtained from 18 different forage plants, found that only 42 per cent was true fat.[15] Of this, 66 per cent was digested, while only 29 per cent of the remainder (not true fat) was digestible.

Certain forage plants of the western ranges, such as the sagebrushes, have a high content of essential oils. (**14**) Though these essential oils have little or no energy value to the animal, they are included in the fat in the usual feed analysis. The actual feeding value of such plants is consequently less than shown by the content of total digestible nutrients.[16]

The ordinary digestion trials give little information concerning the extent to which the mineral matter is actually digested and absorbed, because calcium, magnesium, phosphorus, and iron are chiefly excreted from the body in the feces. Therefore, in a digestion trial these compounds would be reported as largely undigested, though they may really have been digested and absorbed, and later excreted in the feces after being used in the body.

By the use of radioisotopes, such as radiocalcium, the true digestibility of these minerals can be determined. In a digestion trial of this kind, it was found that month-old calves fed milk digested over 90 per cent of the calcium; mature cattle on rations of grain and hay, 30 to 40 per cent; and aged cattle, only 22 per cent.[17]

II. Net Energy and Metabolizable Energy

68. All losses not deducted in digestible nutrient values.—It has been shown previously in this chapter that in determining the amounts of digestible nutrients in a feed, the only loss of nutrients which is deducted is the loss that occurs in the undigested material in the feces. It is assumed that the remainder—the digestible nutrients—is all assimilated and used in the body.

However, this is not strictly true. Energy losses of three other types occur in the digestion and utilization of food. These are:

1. Energy is lost in the urea and other nitrogenous waste products that are excreted in the urine. These compounds have energy value which is lost to the animal. (**51**) This loss of energy is small in the case of feeds which are low in protein and is not very great even in the case of feeds rich in protein.

2. A small amount of energy is lost in the combustible gasses, especially methane, which are produced in the fermentations of cellulose, pentosans, and other carbohydrates in the digestive tract, particularly in the paunch of ruminants. (**44**) The amount of energy lost by this means does not differ much for the various common feeds and is no greater for roughages than for grain and other concentrates. Even in the case of cattle and sheep, the loss is generally less than 10 per cent of the total energy in the feed.

3. A much greater loss of energy

occurs in the various necessary processes of chewing, digesting, and assimilating the food. This is often called the "work of digestion." It is easy to see that energy is required for the movements of the jaws in chewing, for the movements of the digestive tract, and for the increased work of the heart and lungs during digestion. Also, the secretion of the digestive juices requires energy, and there are losses of energy in the heat produced through the bacterial action upon carbohydrates. The energy expended in these processes all takes the form of heat, and it may help to warm the body, if sufficient heat is not otherwise being produced in the body. However, it cannot be used for other purposes, because the body has no ability to convert heat into other forms of energy.

In addition to these losses of energy due to the actual work of chewing, digesting, and assimilating the food, a further loss occurs through the speeding up of the body processes which always follows the eating of food. It has been found that while nutrients are being absorbed from the digestive tract following a meal, more heat is produced than at other times.

This effect is familiar to all of us, for we know that if we eat a meal when we are chilly, we will soon feel decidedly warmer. Likewise, if we eat too heartily in hot weather, we will suffer even more from the heat.

As stated previously, all the losses of energy in the form of heat are often called the "work of digestion." Scientists more commonly use the term *heat increment* to include all these losses, for they are due to the increase, or increment, in heat production of the body that results from the consumption of food.

The *heat increment* is the additional amount of heat which is produced in the body following and because of the consumption of food. It should be borne in mind that it is not the total amount of heat produced in this period, but only the additional amount in excess of the heat produced during a similar period of time before the food was eaten, or in a period when less food was consumed.

The losses of energy in the heat increment are much greater in the case of feeds that are high in fiber than with grain and other concentrates that are low in fiber and therefore readily digested. For example, about 33 per cent of the energy in the nutrients digested from corn grain is used up in this "work of digestion," while this loss is approximately 60 per cent in the case of wheat straw.

69. Net-energy values.—After there is deducted from the total or gross amount of energy in a feed, the energy lost in the feces and by these three other means, there remains what is called the *net-energy value*. This represents the real value of the feed for productive purposes, such as producing growth, body fat, milk, or wool, or in the performance of work. To fix in mind the exact meaning of net-energy values, the following definition should be learned.

The *net-energy value* of a feed is the amount of energy left after there are deducted from its total energy value the amounts of energy lost in: (1) Feces; (2) combustible gases; (3) urine; and (4) heat increment, or "work of digestion."

A certain amount of the net energy supplied by the food must be used to meet the daily maintenance needs of the animal. Even when an animal consumes no food, a certain amount of energy is required for the necessary functions of the body. These include the work of the heart, the lungs, and the other internal organs, as well as the work done by the muscles in producing the movements of the body.

If there is a surplus of net energy left after meeting the requirements for merely maintaining the body, then this surplus may be used for growth, for the formation of body fat, for the production of milk or wool, or for muscular work.

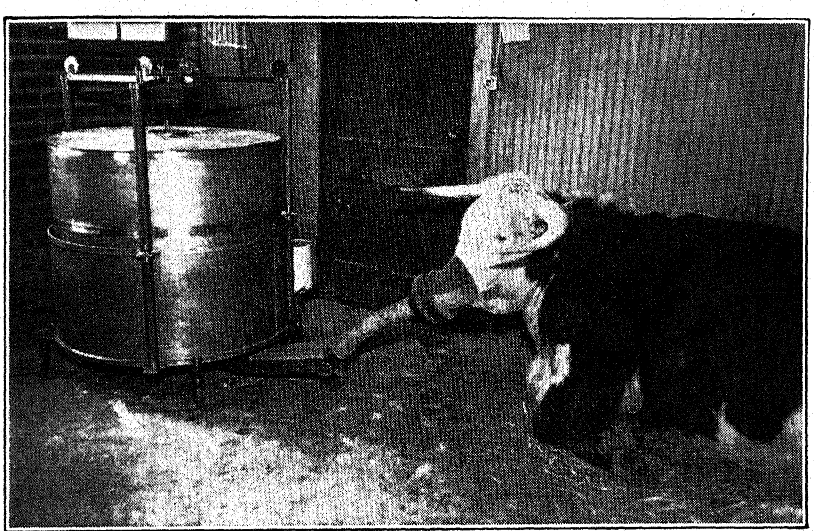
The net-energy value of a feed does not measure its value for maintaining an animal when the weather is cold. This is because no credit is given for the fact

that the heat produced in the "work of digestion" helps to keep the animal warm.

When the temperature of the air surrounding an animal is comfortably warm, enough heat is produced to keep it warm through the oxidations that are always taking place in the body, even when no food is eaten. Under these conditions it gets no benefit at all from the additional heat produced because of the consumption of food (the heat increment).

the remainder is called the *metabolizable energy*. (This is sometimes called *available energy*.) Metabolizable energy shows the value of a feed for maintaining the body temperature, but it does not measure its value for productive purposes.

71. Net-energy values expressed in therms.—In this country the net-energy values of livestock feeds are commonly expressed in therms. A therm, which is a unit for measuring heat, is the amount of heat required to raise the temperature



A SIMPLE TYPE OF RESPIRATION APPARATUS

In this type of respiration apparatus, the air-tight mask over the nose and mouth of the animal is connected to a measuring air-tank. The amount of oxygen used up can be measured, while the carbon dioxide breathed out is absorbed chemically. (From Brody, University of Missouri.)

of 1,000 kilograms of water 1° Centigrade, or to raise the temperature of 1,000 lbs. of water about 4° Fahrenheit.

In studies of human nutrition, the Calorie is used as the unit for measuring heat. The Calorie, known as the large Calorie, is written with a capital C to distinguish it from the calorie (small calorie). One therm is 1,000 Calories or 1,000,000 small calories.

In Europe, net-energy values are generally expressed in terms of starch values, which are explained later in this chapter.

70. Metabolizable energy.—Only the losses of energy in the feces, the combustible gases, and the urine are total losses to an animal. As has been stated previously, the energy used up in the so-called "work of digestion" is all converted into heat. It thus helps to keep the animal warm, if sufficient heat is not otherwise being produced in the body.

For this reason, sometimes only the losses of energy in feces, combustible gases, and urine are deducted from the total amount of energy in the feed, and

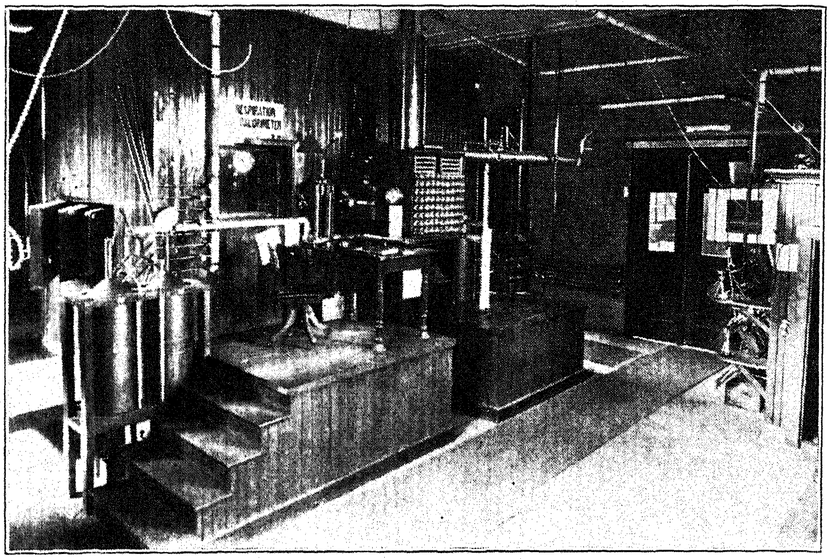
72. Determining net-energy values of feeds.—It is much more difficult and expensive to determine chemically the net-energy value of a feed than to find the amount of total digestible nutrients it supplies. For this reason, the net-energy values of only a very few feeds have been thus found.

First, the gross energy value of the feed is found by burning a weighed sample in pure oxygen gas in an apparatus called a calorimeter, in which the heat given off can be determined accurately. Next, the energy losses in feces and urine are found by collecting and drying these excreta and burning samples in a calorimeter.

It is much more difficult to find the energy lost in the combustible gases and in the heat increment. These losses can be determined only by means of a *respiration apparatus* or a *respiration calorimeter.*

In the simplest type of *respiration apparatus,* the animal breathes through a mask placed over its nose and mouth. The amount of oxygen in the incoming air and in some cases the amount of carbon dioxide breathed out are carefully determined. The energy lost in the combustible gases is not determined in this sort of apparatus, but can be computed from data obtained in other experiments, since this loss is small and relatively constant for any type of animal.

Apparatus of this kind is now used in most large hospitals to find the rate of metabolism in humans suffering from certain diseases. This method has been used in extensive studies by Brody and associates at the Missouri Station to find the energy expenditure of farm animals of various classes and under different conditions.



RESPIRATION CALORIMETER AT PENNSYLVANIA STATION

Much important information concerning the nutritive values of different classes of feeds has been secured through the investigations conducted with this apparatus. (From Pennsylvania Institute of Animal Nutrition.)

In the more complete type of respiration apparatus, the animal is confined in an air-tight chamber, equipped so that the air entering and leaving can be accurately measured and analyzed. Extensive studies with farm animals have been made by Kellner, Möllgaard, and other European scientists with apparatus of this kind, and in this country by Ritzman and successors at the New Hamp-

shire Station, by Mitchell at the Illinois Station, and by Kleiber at the California Station.

The *respiration calorimeter* resembles this latter type of respiration apparatus, but in addition is equipped with elaborate devices by means of which the heat given off by the animal can be directly determined. The only respiration calorimeter built in this country for experiments with farm animals was erected years ago by Armsby at the Pennsylvania Station. After his death, the investigations were continued by Forbes and associates and later by Swift and associates. During recent years this respiration calorimeter has unfortunately been used but little, because of the great amount of time and expense required in such experiments.

Another method of determining net-energy values is to analyze the entire bodies of growing animals that have been fed the test ration during an experimental period of sufficient length. This method has been used by Fraps of the Texas Station to determine the net-energy values of various feeds for growing chickens.[18] It would be very difficult and expensive to use the method with the larger farm animals.

Approximate net-energy values can be determined rather easily by a method proposed by the author of this volume. In this method, which is described later, certain modifications are made in the usual type of practical feeding experiment. (81) Other feeds are directly compared with corn grain as a standard, since reliable net-energy values for corn have been determined in energy investigations.

The approximate net-energy value of any feed for a particular class of stock can also be computed, if a sufficient number of ordinary feeding experiments have been conducted to compare this feed with other standard feeds. This is the method that has been chiefly used by the author in computing the estimated net-energy values given in Appendix Table II of this volume.

Moore and associates have also developed formulas for estimating the net energy values of various feeds from the content of total digestible nutrients.[19] Data are insufficient to determine whether these formulas can be used for feeds very high in fiber, such as peanut hulls.

73. Net-energy values of nutrients and typical feeds.—The various losses of energy that occur in the use by cattle of pure digestible nutrients and of typical feeds are shown in the following table. This is based on the investigations by Kellner with a respiration apparatus and by Armsby with the respiration calorimeter.

It will be noted that peanut oil, a fat, had much more gross energy than the other nutrients. This is because fats contain a much larger proportion of carbon and hydrogen and less oxygen than do carbohydrates or protein. The gross-energy value of protein is also somewhat higher than that of carbohydrates.

In the case of the pure nutrients, peanut oil or wheat gluten, there was no loss of energy in the form of combustible gases because fat and protein, as such, do not undergo the fermentations in the paunch and large intestine which produce these gases. However, in the case of starch, a loss of 17.3 therms of energy occurred in combustible gases for each 100 lbs. of the nutrient. No loss of energy in the urine resulted in either peanut oil or starch since they contained neither protein or other nitrogenous compounds.

With ruminants fed pure nutrients such as fat, protein, and carbohydrates as used in these experiments there are losses in the feces and other excreta of the body. This loss amounted to 188.8 therms for peanut oil, 55.4 therms for wheat gluten, and 33.6 therms for starch. (When these same nutrients are fed to simple stomached animals, such as swine, much better utilization is secured and the losses in this manner are negligible.)

After all of these various losses were deducted there remained 241.0 therms of *metabolizable* energy for the fat, 164.5 therms for the protein, and 137.5 therms for the starch. The losses in heat increment, often incorrectly called, "work of digestion," were highest in the case of

protein and lowest for starch. Deducting all losses, there remained 163.8 therms of energy from 100 lbs. of fat; 68.3 therms from protein; and 81.0 therms from starch.

It is important to note that although protein contained considerably more gross energy than did starch, the losses were so much larger that it furnished a less amount of net energy. The net-energy value of protein represents the value of food protein that is supplied in excess of the actual needs of the animal for protein. It is the worth of protein as a substitute for starch or fat in the production of heat, energy, or body fat. Protein has its full value only when used for the repair of protein tissue, for the building of new body protein, or for making the protein in milk.

It should be noted that in computing the total digestible nutrients of feeds, digestible protein is given the same value as digestible carbohydrates, instead of being given any higher value.

Practical feeding experiments which are reviewed in later chapters have shown clearly that a protein supplement such as soybean oil meal or cottonseed meal has a much higher value than corn grain, when the necessary amount is added to balance a protein-poor ration. However, when a large amount of the protein supplement is fed as a corn substitute, the excess amount is usually worth a little less than corn, instead of more than the grain.

74. Net-energy values of concentrates and roughages.—The table shows that wheat straw, which is a very low-grade feed, has fully as high a gross-energy value per 100 lbs. as does ground corn or timothy hay. This means merely that it will produce as much heat on being burned. While the gross-energy values of these feeds are approximately the same, there are great differences in the losses which occur in them.

Net energy value of pure nutrients and typical feeding stuffs (for ruminants, per 100 lbs., air-dry basis)

Nutrients or feeding stuffs	Gross energy	Energy lost in: Feces & other excreta	Urine	Combustible gases	Metabolizable energy remaining	Heat increment	Net energy
	Therms	Therms	Therms	Therms	Therms	Therms	Therms
Pure nutrients							
Peanut oil (fat)	429.0	188.8	0.0	0.0	241.0	77.2	163.8
Wheat gluten (protein)	253.1	55.4	33.2	0.0	164.5	96.2	68.3
Starch (carbohydrate)	188.4	33.6	0.0	17.3	137.5	56.5	81.0
Common feeding stuffs							
Ground corn	177.7	18.6	8.0	17.8	133.3	51.5	81.8
Timothy hay	182.4	86.9	7.3	13.4	74.8	31.0	43.8
Wheat straw	186.7	109.6	3.7	15.5	57.9	48.5	9.4

In the case of corn, which is highly digestible, only 18.6 therms of energy were lost in the feces. Because of the lower digestibility of hay, 86.9 therms were lost in the feces per 100 lbs. of timothy hay. Wheat straw was digested so poorly that more than one-half of the original gross-energy content was lost.

There was little loss of energy in the urine with all of these feeds, for none of them is high in protein.

The loss of energy in combustible gases was also small for all of the feeds, amounting to less than 10 per cent of the gross-energy content.

Deducting the losses in feces, combustible gases, and urine, there remained 133.3 therms of *metabolizable energy*

from 100 lbs. of corn; 74.8 therms from hay; and only 57.9 therms from the straw. After the energy lost in heat increment is subtracted from the metabolizable energy for these feeds, the energy remaining, or *net-energy* value is 81.8 therms, for corn; 43.8 therms for hay; and 9.4 therms for straw.

It is sometimes said that no more energy is lost in the "heat increment" per 100 lbs. in the case of roughages than with corn or other concentrates. While this is literally true, it is a misleading basis of comparison. The comparison should be made on the basis of the *proportion* of the metabolizable energy which is lost in the "heat increment."

Comparing ground corn and wheat straw on this basis, it will be found that in the case of the straw 84 per cent of the metabolizable energy was lost in the heat increment. With the ground corn only 39 per cent of the metabolizable energy was lost by this means.

These data show that for productive purposes, such as the formation of body fat, 100 lbs. of wheat straw were worth less than one-eighth as much as 100 lbs. of corn grain and only one-fourth as much as 100 lbs. of timothy hay. For the production of heat in the body, the relative values of these feeds are measured by their metabolizable-energy values. Total digestible nutrients furnished by various feeds are also approximate measures of their relative values for this purpose.

75. Maintaining animals in cold weather.—It has been mentioned previously that net-energy determinations are practically always made with animals in an air temperature such that they get no benefit from the heat lost in the "heat increment." (68) For this reason such net-energy values should not be used in computing maintenance rations for wintering farm animals in sections where the winter climate is cold. It is shown in Chapter VIII that the chief maintenance requirement in cold weather is for heat to keep the body warm. The usual net-energy values seriously undervalue the worth of roughages for this purpose. In computing rations for maintaining stock in winter, it is therefore more accurate to use total digestible nutrients. Metabolizable-energy values are also suitable for this purpose, but are not in common use.

The fact that roughages have a much higher relative value for warming the body than they do for productive purposes, is of great importance in livestock feeding. It is pointed out in later chapters that mature animals that are merely being maintained, such as idle horses in winter, can be satisfactorily kept on roughages alone, even those of rather low quality. On the other hand, high-producing dairy cows, fattening cattle or sheep, and horses at hard work can make but little use of low-grade roughage, such as straw or poor, woody hay.

76. Metabolizable energy for valuing feeds.—Some investigators advocate the use of metabolizable-energy values for valuing various feeds and for computing rations, instead of net-energy values or total digestible nutrients.

Except in the case of poultry, this does not seem desirable to the author. As is pointed out in Chapter XXXVI, in poultry the feces and urine are not voided separately. It is therefore impossible to determine the digestible nutrients by the usual methods. However, the metabolizable energy in a ration can be found by determining the energy content of the feed and of the combined feces and urine. Metabolizable-energy values are therefore useful measures of the values of poultry feeds.

In the case of other farm animals, metabolizable-energy values do not furnish a much better index to the relative values of feeds high in fiber and those low in fiber than do total digestible nutrient values. It is much more difficult to determine metabolizable-energy values experimentally, than to find the digestibility of feeds. Some have advocated the computation of metabolizable-energy values from the amounts of digestible nutrients by the use of various factors.[20] Such computed values can be only very approximate. Therefore the author prefers to use either total digestible nutrients, with their acknowledged

limitations, or else to use estimated net-energy values, such as are given in Appendix Table II.

It should be borne in mind that in the common method of computing total digestible nutrients, the unavoidable loss of energy in the urine is approximately corrected. This is because digestible protein is given the same value as digestible carbohydrates. Protein actually has a considerably higher energy or fuel value than carbohydrates, but part of the energy is lost in the urine.

77. Net-energy values vs. total digestible nutrients.—There is no question but what net-energy values are theoretically more accurate than total digestible nutrients for comparing the values of roughages or low-grade concentrates with the values of the grains and other high-grade concentrates for productive purposes. This is because there is a decidedly greater loss of energy in the heat increment from each pound of digestible nutrients in the case of feeds high in fiber than with those low in fiber. Therefore each pound of total digestible nutrients in roughage or low-grade concentrates has a lower productive value than in high-grade concentrates.

Any person experienced in livestock feeding will agree that the relative value of good hay and of straw for production is far different from the amounts of total digestible nutrients in such hay and in straw. For example, average alfalfa hay has 50.7 lbs. total digestible nutrients per 100 lbs.; average grass hay, 44 to 47 lbs.; and oat straw, 44.8 lbs. No experienced stockman believes that oat straw is really worth over four-fifths as much as good alfalfa hay, or nearly as much as average grass hay, for stock being fed for production.

Unfortunately, there are decided limitations in the use of net-energy values. First of all, on account of the great cost of such investigations, the values of but very few feeds have been actually determined by experiments with a respiration calorimeter or a respiration apparatus. For example, though most such studies have been with fattening steers, the net-energy values of less than 20 feeds have been directly determined for this class of stock. The net-energy values for other feeds must therefore be estimated from the best data available.

78. Factors affecting net-energy values.—It has been pointed out previously in this chapter and is explained further in the next chapter that the digestibility of any feed varies somewhat, being influenced by several factors. **(101–106)** It is therefore necessary to average together the results of several well-conducted digestion trials to have a reliable basis for computing the average amounts of digestible nutrients supplied by any feed.

Net-energy values are considerably more variable than total digestible nutrients. First of all, there is apt to be a greater difference in the results secured with individual animals of the same kind and kept under the same conditions.[21] This may be due to the complexity of net-energy investigations.

The net-energy value of the same feed or of the same ration is also affected by the amount of feed that is given the animal. When an animal is scantily fed, the net-energy value of the ration per pound may be 20 per cent higher than when the animal is fed liberally.[22] It is pointed out in the next chapter that the amount of feed eaten also affects the digestibility of a ration, but to a much less degree.

Any nutritive deficiency in a ration may seriously reduce its net-energy value, especially if the deficiency is long continued. The effect is apt to be greater than the effect upon digestibility. In experiments by Forbes and associates a deficiency in the amount or quality of protein, or a deficiency of fat, of minerals, of thiamine, or of riboflavin decreased the net-energy values of rations for rats used as test animals.[23]

It has been found that the same feeds have decidedly different net-energy values for some classes of stock than for others. Thus, the net-energy value of a ration for mere body maintenance or for milk production was 23 to 24 per cent higher than for the fattening of cattle.[24] For swine or poultry the net-energy val-

ues of such high-grade concentrates as the cereal grains are much higher than for fattening cattle.[25] On the other hand, because swine and poultry have little ability to digest fiber, feeds high in fiber have very low net-energy values for them.

The net-energy values of high-grade concentrates are much higher for horses than for fattening cattle.[26] However, hay has a much lower net-energy value for work horses than for cattle, and wheat straw actually has a negative value. In other words, the more straw the horse eats, the less work he can do.

In addition to the effect of all of these factors, the net-energy value of a feed may be affected by the particular combination of feeds with which it is fed, even though all of the rations are balanced in protein and other nutrients. As is pointed out in the next chapter, scientists differ in their opinions concerning the importance of such "associative action" of feeds. (**104**)

79. Net-energy values in Appendix Table II.—In spite of these limitations of net-energy values, the author believes that it is possible to evaluate the most important feeds more correctly on the net-energy basis than by using the values for total digestible nutrients. He has therefore computed estimated net-energy values for the most important feeds, which are presented in Appendix Table II. These values are based upon studies of all the available data that provide information concerning the relative values of these feeds for productive purposes. The reader can decide whether to use the total-digestible-nutrient values in Appendix Table I or these estimated net-energy values in Appendix Table II. The author has endeavored to make both tables as useful and reliable as possible.

In computing the estimated net-energy values in Appendix Table II, chief reliance has been placed on the results of the hundreds of feeding experiments conducted by the experiment stations to compare the values of different feeds for fattening cattle and sheep, for dairy cows, and for swine. The other sources of data used in the preparation of this table are stated in the paragraphs that precede the table.

The net-energy values in Appendix Table II are primarily for growing and fattening livestock. As has been mentioned previously, the various feeding stuffs have higher net-energy values for milk production than for the fattening of animals. However, the *relative* net-energy values of different feeds for milk production and for fattening are probably not far different in most cases. Also, in the case of feeds which seem to have different relative values for dairy cows than for fattening stock, separate values are given for dairy cows.

Therefore, those desiring to compute rations for dairy cows on the net-energy basis can safely employ these net-energy values, using the figures for net-energy requirements given in Appendix Table III, which are designed for use with these net-energy values. These values can also be used in computing rations for work animals.

These net-energy values should not be used in computing rations for merely maintaining animals during cold weather. It is much more accurate to use for this purpose the total-digestible-nutrient values in Appendix Table I.

80. Roughages compared with concentrates.—An inspection of Appendix Table II will show that there is a considerably greater difference between the net-energy value of a high-grade concentrate and that of a dry roughage than there is between the percentages of total digestible nutrients furnished by the same feeds. For example, dent corn of Grade No. 1 supplies 81.9 therms of net-energy per 100 lbs., while timothy hay (all analyses) furnishes but 37.3 therms, or only 46 per cent as much. However, timothy hay has 60 per cent as much total digestible nutrients as does corn grain. It has 49.1 per cent total digestible nutrients, in comparison with 81.9 per cent for No. 1 dent corn.

In the case of lower-grade roughages, such as corn stover and straw, the difference between the valuations of feeds by these two systems is even greater. For instance, wheat straw has

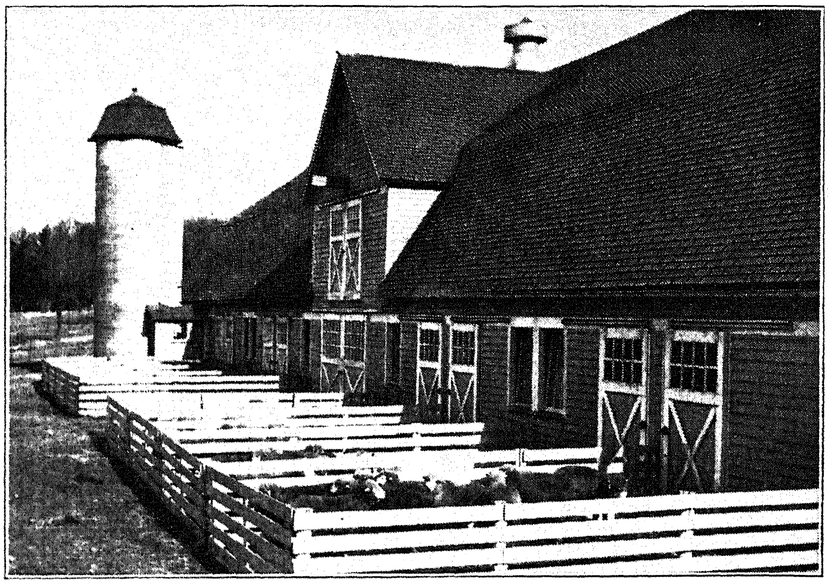
40.6 per cent total digestible nutrients, which is nearly one-half as much as dent corn. However, the straw furnishes only 10.0 therms of net energy per 100 lbs., or but one-eighth as much as does corn grain.

The reason why the net-energy values of roughages are much lower than their total digestible nutrient values has been stated previously in this chapter. It is chiefly because the losses of energy in the heat increment, or the so-called "work of digestion," are much greater in the case of feeds high in fiber than with the grains and other concentrates that are low in fiber and therefore readily digested. Therefore, when one wishes to compare the value of a roughage for productive purposes with that of a concentrate, it is more accurate to use net-energy values than to base the comparison on total digestible nutrients.

81. Determining net-energy values by feeding experiments.—It has been pointed out previously in this chapter that net-energy determinations with large farm animals are so time-consuming and expensive that such values have been obtained experimentally for very few feeds. Even for these feeds, the values were determined with only a few individual animals.

The author therefore proposed a method by which approximate net-energy values, or production values, for various feeds can be determined rather easily, by making certain modifications in the usual type of feeding experiment.[27] In this method other feeds can be compared with corn grain as a standard, since reliable net-energy values for corn have been determined in energy investigations.

To illustrate the method, let us suppose that we wish to find the approximate net-energy value, or production value, of alfalfa hay for fattening lambs, in comparison with that of corn grain. One experimental lot of lambs is fed under regular feed-lot conditions a limited amount of corn grain with a very liberal amount of hay, but no more hay than the lambs will clean up with little waste.



NET-ENERGY VALUES CAN BE FOUND IN FEEDING TRIALS

Experimental sheep barn at Cornell University where feeding experiments to determine the approximate net-energy values of various feeds have been conducted.

Another lot of similar lambs is fed considerably less hay per day. In addition, they are fed *just enough corn* to make the same gain in liveweight as is made by the lambs in the first lot. At the end of the experiment when the lambs are ready for market, the production of both lots will have been equal, so far as gain in weight is concerned. Taking the well-established net-energy value of corn grain as the standard, the approximate net-energy value of the alfalfa hay can be then computed from the amounts of corn and hay required by the two lots to produce the same gain in weight.

By careful slaughter tests it can be determined whether there is any observable difference in fatness of the carcasses of the lambs fed the two rations. If such a difference is found, a correction can be applied to the estimated net-energy value of the hay, to correct for the difference in energy value of the gain made on the two rations. This correction can be based upon data which are available concerning the energy content of the carcasses of animals of various degrees of fatness. Except for the great expense involved, it would be preferable to make chemical analyses of the carcasses of all of the lambs.

Because the method is simple and not very expensive, experiments can readily be repeated a sufficient number of times and with enough animals to eliminate most of the variations due to individuality of animals or to differences in composition of the same kind of feed. Also, since such experiments can be conducted under practical conditions, they should furnish more reliable information than we have at present concerning the productive values of most feeds.

This method has been used by the author and associates at the New York (Cornell) Station and by other investigators at the Colorado, Maryland, Michigan, and Oklahoma Stations.[28] It is suitable for use with dairy cows, as well as with fattening or growing animals.

82. Starch values.—Kellner, who conducted extensive investigations many years ago in Germany with steers in a respiration apparatus, measured the values of feeds for productive purposes in terms of *starch values,* instead of net-energy values stated in therms.[29] In this system 1 lb. of digestible starch is taken as the net-energy unit. The net-energy value of any feeding stuff is expressed as the number of pounds of starch which is believed to have the same net-energy value for productive purposes. Thus, the starch value of dent corn, according to the Kellner method, is 81.5 lbs. starch equivalent per 100 lbs.

Kellner also prepared feeding standards based on digestible true protein and starch values. These were a decided improvement over the old Wolff-Lehmann standards and were therefore widely adopted in Europe. Because of the great advance in our knowledge about animal nutrition since then, the Kellner values should now be considered as of only historical importance.

83. Armsby net-energy values.—From factors based on his net-energy investigations with steers and on the experiments of Kellner, Armsby computed net-energy values for a considerable list of feeds. These were published in 1917 in his book, *The Nutrition of Farm Animals.*

Since the net-energy values of only a very few feeds had actually been determined, most of his values were computed from the table of digestible nutrients in the fifteenth edition of *Feeds and Feeding* with the permission of the writer. Unfortunately, his method of computation was faulty, and as a result some of his values were decidely incorrect.

For example, the value of barley for all fattening ainmals is definitely lower than that of corn. Yet, Armsby's net-energy value per 100 lbs. was 89.94 therms for barley, in comparison with only 85.50 therms for dent corn. This was due primarily to the fact that in Armsby's method of computation corn was given no credit for the fact that it has twice as much fat as barley. Similarly, soybeans, flax seed, and other fat-rich feeds were given lower energy values than barley or wheat, while the values should have been much higher than for these grains.

Fully as important as these differences was the fact that lower net-energy values were assigned to all the legume hays than to timothy hay and other grass hay. For example, a net-energy value of only 34.23 therms was given for average alfalfa hay, while the value for average timothy hay was 43.02 therms. Red top hay, a grass hay

which is usually of rather poor quality, was given a value of 51.22 therms.

The Armsby net-energy values or the Kellner starch values have never been widely used in this country. This is probably because their limitations have been realized more clearly than in some other countries. The author believes that the Armsby values, like the Kellner starch values, should now be considered as having only historical importance.

84. Scandinavian feed-unit system.—The Scandinavian feed-unit system of valuing feeds is widely used in the Scandinavian countries for measuring the relative values of different feeds.[30] In this system the value of 1 lb. of barley grain is taken as the standard.

The feed-unit value for any other feed is the amount of that feed which is estimated to have the same productive value as 1.00 lb. of barley. For example, the feed unit values of soybean oil meal and of cottonseed meal for dairy cows are given as 0.85 lb. and the value of corn grain as 0.95 lb. This means that according to the estimate, it takes 0.85 lb. of soybean oil meal or cottonseed meal, or 0.95 lb. of corn, to equal 1.00 lb. of barley in feeding value.

The feed-unit values are not true expressions of net energy, for in this system feeds rich in protein are given higher values than feeds low in protein which actually furnish the same amount of net energy. The high value given to protein in the feed-unit system is undoubtedly the result of the character of the rations employed in the experiments. In the Scandinavian countries there is a shortage of protein in the home-grown feeds, and considerable amounts of protein supplements are imported. Therefore, the common rations are often rather low in protein. When added to rations which are somewhat too low in protein content, 1.0 lb. of a protein supplement naturally had a higher productive value than 1.0 lb. of barley.

The conditions in the various parts of the United States differ much more than in the Scandinavian countries. In the corn belt there is commonly a shortage of protein in the farm-grown feeds. On the other hand, in the alfalfa districts of the West, the shortage is often one of carbohydrates, and not of protein. Similarly, in the cotton belt of the South cottonseed meal is sometimes cheaper per ton than grain. Under these latter conditions, protein-rich feeds obviously do not have higher feeding values than correspond to the amounts of net energy or of total digestible nutrients that they provide. Probably because of these conditions, the feed-unit system has never been used widely in the United States.

85. Möllgaard's values.—Möllgaard conducted extensive respiration studies with dairy cows in Denmark and published feed units for milk production, or production units, of a somewhat different kind.[31] For feeds for which values have not been determined experimentally, values were computed from Kellner's starch values, or from the content of digestible nutrients. In his values recognition is given to the fact that the net-energy values of feeds are higher for milk production than for fattening animals.

86. Fraps' production values.—From extensive studies of the results of feeding experiments in which various feeds were compared, Fraps of the Texas Station computed net-energy values expressed in therms for a considerable list of feeds.[32] He called these values productive-energy values.

Fraps' values seem to be much more accurate estimates of the values of different feeds for productive purposes than Kellner's starch values or Armsby's net-energy values. For this reason considerable use was made of the Fraps' values in preparing the estimated net-energy values in Appendix Table II of this volume.

Fraps also determined net-energy values of various feeds for chicks by the method mentioned previously. (72)

QUESTIONS

1. Show, by examples, why the information gained by extensive feeding experiments is the most reliable method of estimating the relative value of different feeding stuffs for the various classes of stock.
2. Define *digestion coefficient*. How are the digestion coefficients determined directly, and also by difference, in digestion trials?
3. What is the relative digestibility of feeds low in fiber and of those high in fiber?
4. Define *total digestible nutrients*. State how the amount of total digestible nutrients is computed.
5. Define *nutritive ratio* and show how it is computed. What is meant by the term *narrow nutritive ratio;* the term *wide nutritive ratio?*
6. State three other methods for determining digestibility.
7. What 3 losses of food energy are not deducted in determining the amount of digestible nutrients in a feed?
8. Define the *net-energy value* of a feed.

For what purposes may net energy be used in the body?

9. In what terms are net-energy values generally expressed in the United States?
10. Describe a respiration apparatus. How does a respiration calorimeter differ from a respiration apparatus?
11. By what other means can net-energy values be determined?
12. Why are net energy values more accurate than total digestible nutrients for comparing the values of roughages and of concentrates for productive purposes?
13. Why may considerable straw be fed advantageously to an idle horse, but not to one at hard work?
14. Why does not the net-energy value of a roughage measure its value for maintaining stock in the winter in most sections of the United States? On what basis should maintenance rations for such animals be computed?
15. Discuss the factors which affect net-energy values. Consider (a) amount of feed; (b) nutritive deficiencies; (c) kind of animal.
16. How can approximate net-energy values be determined by feeding experiments?

REFERENCES

1. Schneider, Lucas, Cipolloni, Pavlech, W. Va., Jour. Anim. Sci., 11, 1952, pp. 77–83.
2. Schneider, Feeds of the World, Their Digestibility and Composition, 1946.
3. Lofgreen, Cal., Jour. Anim. Sci., 12, 1953, pp. 359–365.
4. Reid, N.Y., Proc. Cornell Nutr. Conf. for Feed Manufacturers, 1950.
5. Lofgreen, Cal., Jour. Anim. Sci., 10, 1951, pp. 344–351; Schneider and Pavlech, Wash., Jour. Anim. Sci., 9, 1950, p. 667; Maynard, Animal Nutrition, 3rd. ed., 1951, p. 291.
6. Schneider, Wash., unpublished data cited by Maynard, Jour. Nutr., 51, 1953, pp. 15–22.
7. Lucas, N.C., Science, 116, 1952, pp. 301–302.
8. Forbes and Garrigus, Ky., Jour. Anim. Sci., 9, 1950, pp. 354–362, 531–539; Plummer, Banton, and Dickey, Maine Bul. 491; Hale, Duncan, and Huffman, Mich., Jour. Dairy Sci., 23, 1940, pp. 953–967; Ellis, Matrone, and Maynard, N.Y., Jour. Anim. Sci., 5, 1946, pp. 285–297; Richards and Reid, N.Y., Jour. Dairy Sci., 35, 1952, pp. 595–602; Kane, Ely, Jacobson, and Moore, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 325–333, 346–355; Sullivan, U.S.D.A., Jour. Anim. Sci., 14, 1955, pp. 710–717.
9. Smith and Reid, N.Y., Jour. Dairy Sci., 38, 1955, pp. 515–524; Dansky and Hill, N.Y., Jour. Nutr., 47, 1952, pp. 449–468, Clawson, Reid, Sheffy, and Willman, N.Y., Jour. Anim. Sci., 14, 1955, pp. 700–709; Kane, Ely, Jacobson, and Moore, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 325–333; Crampton and Lloyd, Canada, Jour. Nutr., 45, 1951, pp. 319–327; Schürch, Crampton, Haskell and Lloyd, Canada, Jour. Anim. Sci., 11, 1952, pp. 261–265; Lancaster, Coup, and Percival, New Zealand Jour. Sci. Tech. (Sect. A), 35, 1953, p. 117; Raymond, Kemp, Kemp, and Harris, Jour. British Grassland Soc., 9, 1954, p. 69.
10. Reid et al., N.Y., Jour. Dairy Sci., 33, 1950, pp. 60–71; Anthony et al., Ala., Jour. Anim. Sci., 13, 1954, p. 1004; McCullough, Elliott, and Bastin, Ky., Jour. Dairy Sci., 34, 1951, pp. 494–495; Irvin, Wiseman, Shaw, and Moore, Md. and U.S.D.A., Jour. Anim. Sci., 12, 1953, pp. 541–551; Irvin and Wiseman, Md. and U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 582–583; Smart, Matrone, and Smart, N.C., Jour. Agr. and Food Chem., 2, 1954, pp. 1331–1332; Reid et al., N.Y., Jour. Nutr., 46, 1952, pp. 255–269; Hardison, Reid, Martin, and Woolfolk, N.Y., Jour. Dairy Sci., 37, 1954, pp. 89–108; Cook and Harris, Utah, Jour. Anim. Sci., 10, 1951, pp. 565–573; Kane and Jacobson, U.S.D.A., Jour. Dairy Sci., 37, 1954, p. 672; 38, 1955, p. 625; Brisson, Angus, and Sylvestre, Canadian Jour. Agr. Sci., 34, 1954, pp. 528–532.
11. McCullough, Ga., Jour. Dairy Sci., 36, 1953, pp. 445–449; Mahaffey, Miller, Donker, and Dalton, Ga., Jour. Dairy Sci., 37, 1954, p. 672; Noller, Hill and Lundquist, Ind., Jour. Anim. Sci., 10, 1951, p. 1072; Woolfolk et al., Ky., Jour. Anim. Sci., 14, 1955, pp. 1241–1242; Hardison and Reid, N.Y., Jour. Nutr., 51, 1953, pp. 35–52; Brannon, Reid, and Miller, N.Y., Jour. Anim. Sci., 13, 1954, pp. 535–542; Smith and Reid, N.Y., Jour. Dairy Sci., 38, 1955, pp. 515–524; Hardison, Engel, Graf, and Linkous, Va., Jour. Dairy Sci., 37, 1954, p. 665; Schneider, Soni, and Ham, Wash., Jour. Anim. Sci., 12, 1953, pp. 722–730; Kane, Jacobson, Ely, and Moore, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 637–644.
12. Forbes, Ky., Jour. Anim. Sci., 8, 1949, pp. 19–23; 9, 1950, pp. 231–237; Gallup and Briggs, Okla., Jour. Anim. Sci., 7, 1948, pp. 110–116; Schneider, Soni, and Ham, Wash., Jour. Anim. Sci., 12, 1953, pp. 722–730; Soni et al., Wash., Jour. Anim. Sci., 13, 1954, pp. 474–479; Kane, Jacobson, Ely, and Moore, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 637–644; Lancaster, England, Nature, 163, 1949, p. 330; Homb and Breirem, Norway, Jour. Anim. Sci., 11, 1952, pp. 496–500.
13. Gehrt, Caldwell, and Elmslie, Jour. Agr. and Food Chem., 3, 1955, pp. 159–162.
14. Schneider, Lucas, Pavlech, and Cipolloni, W. Va., Jour. Anim. Sci., 9, 1950, pp. 373–379.
15. Fraps and Rather, Tex. Bul. 150.
16. Cook, Stoddart, and Harris, Utah, Jour. Anim. Sci., 11, 1952, pp. 578–590.
17. Hansard, Comar, and Davis, Tenn. and Fla., Am. Jour. Physiol., 177, 1954, pp. 383–389.
18. Fraps, Texas Buls. 665, 678.
19. Moore, Irvin, and Shaw, U.S.D.A. and Md., Jour. Dairy Sci., 36, 1953, pp. 93–97.
20. Axelsson, Kungl. Lantbruksakademiens Tidskrift, 80, 1941, No. 5, pp. 353–364; Axelsson, Tierernährung, 10, 1938, pp. 238–248; see also: Forbes et al., Penn. Bul. 452; Mitchell, Jour. Anim. Sci., 1, 1942, pp. 159–173.
21. Meigs, U.S.D.A., Jour. Dairy Sci., 8, 1925, pp. 523–536.
22. Forbes, Braman, Kriss et al., Penn., Jour. Agr. Res., 40, 1930, pp. 37–78.
23. Forbes, Braman, Kriss, et al., Penn., Jour. Agr.

Res., 43, 1931, pp. 1015–1026; Braman, Black, Kahlenberg, Voris, Swift, and Forbes, Penn., Jour. Agr. Res., 50, 1935, pp. 1–38; Forbes et al., Penn., Jour. Nutr., 8, 1934, pp. 197–219; 8, 1934, pp. 295–308; Kahlenberg, Black, and Forbes, Penn., Jour. Nutr., 13, 1937, pp. 97–108; Black, Kahlenberg, Bratzler, and Forbes, Penn., Jour. Nutr., 14, 1937, pp. 521–533; see also: Mitchell, Hamilton, and Haines, Ill., Jour. Agr. Res., 1940, pp. 847–864.

24. Forbes, Fries, Braman, and Kriss, Penn., Jour. Agr. Res., 33, 1926, pp. 483–492; Möllgaard, Grundzüge die Ernährungs-physiologie der Haustiere, 1931.

25. Mitchell and Haines, Ill., Jour. Agr. Res., 34, 1927, pp. 927–943; Fraps, Texas Buls. 665, 678; Breirem, Beret, Forsogslab. K. Vet. og. Landbojskoles, Denmark, 162, 1935, pp. 1–269.

26. Zuntz, Landw. Jahrb., 27, 1898, Sup. III.

27. Morrison, Amer. Soc. Anim. Prod., Proc. 1937.

28. Morrison, Amer. Soc. Anim. Prod., Proc. 1937; Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834, pp. 28–33; Cairns, Cornell Univ., Abstract of Ph.D. Thesis, 1940; Leinbach, Colo., Amer. Soc. Anim. Prod., 1939; Leinbach, Cornell Univ., Abstract of Ph.D. Thesis, 1941; Leinbach, Md. Rpt., 1940, and mimeo. rpts; Blakeslee and Brown, Mich. Quar. Bul., 23, 1940, No. 2; Briggs, Okla. Bul. B-252; Briggs, Okla., Jour. Anim. Sci., 2, 1943, pp. 336–355; Taylor and Blizzard, Okla., Jour. Anim. Sci., 1, 1942, pp. 353–354.

29. For a detailed explanation of starch values see Kellner's books, *Ernährung landw. Nutztiere* and *Fütterungslehre*, and the English translation of the latter book by Goodwin, entitled *The Scientific Feeding of Farm Animals.* This method is also discussed in some detail in Wood's book *Animal Nutrition.*

30. For a discussion of the feed-unit system see; Woll, Wis. Cir. 37; Hansson, Utfodringslära; Hansson, Fühling's Landw. Zeit., 65, 1916, p. 314.

31. Möllgaard, Fütterungslehre des Milchviehs, 1929; Möllgaard, Grundzüge der Ernährungs-physiologie der Haustiere, 1931.

32. Fraps, Texas Bul. 436; see also: Fraps, Texas Buls. 185, 329, 402, 461.

CHAPTER IV

FACTORS AFFECTING THE VALUE OF FEEDS

I. The Preparation of Feeds

87. When does preparation of feed increase its value?—It is of much financial advantage to stockmen to know whether or not any particular method of preparing feed for farm animals is profitable. Extravagant advertising claims are sometimes made concerning the supposed savings that will result from a certain method of preparing feed. It is therefore highly important that a farmer have reliable information on this subject, before spending money for equipment.

It is often assumed that by grinding or chopping feed much labor is saved the animal and that the value of the feed is therefore increased decidedly. This idea is based on the supposition that the less work the animal does in mastication and digestion, the greater will be the amount of nutrients left for useful production.

However, this is apparently not true. Making feeds so fine and soft that they can be swallowed with little chewing, not only fails to pay for the cost of such preparation, but it may actually lower the value of the feed.

The value of grinding, crushing, or chopping feed depends on the character of the particular feed in question and also on the kind of animal to which it is to be fed. Therefore the economy of these methods of preparing feed for each class of stock is considered in detail in later chapters. In this chapter there are discussed only certain general principles that apply to the various classes of feeding stuffs and to the different kinds of livestock.

In some cases, feeds that are unpalatable to stock will be consumed readily if they are ground and mixed with those that are well liked. For example, rye gives better results with most classes of stock if it is mixed with more palatable grains.

To induce animals that are being fitted for show to consume a little more feed than they might otherwise, the grinding of grain, the chopping of hay, or the soaking of feed may sometimes be helpful, even though the expense of such preparation would not be justified for other stock. There will naturally be more saving in grinding feed for animals with poor teeth than for those that can chew their food normally.

88. Grinding grain or other seeds.—In the case of grain or other seeds, grinding, crushing, or soaking is usually profitable only when the particular animals fail to chew the seeds thoroughly. Seeds that escape chewing may pass through the digestive tract without appreciable digestion, and thus the nutrients are lost. Whether or not it will pay to grind grain for any class of stock is therefore a problem that can be determined only by actual feeding experiments with that class of animals.

Such preparation may be advisable for very young animals, before their teeth are well developed, but later it may not be beneficial. Also, in certain instances animals chew their feed less thoroughly as they grow older, and the grinding of grain is then advisable, even though it may not have been worth while for the same animals when somewhat younger.

For example, after they are a few weeks old, calves chew corn or oats thoroughly up to about 6 or 9 months of age, and there is hence no advantage in grinding these grains for them. After this age, it usually pays to grind the grains. Similarly, growing and fattening pigs chew corn with such thoroughness up to the usual market weights, that it does not generally pay to grind it for

them. However, older pigs chew corn less thoroughly, and therefore the saving through grinding is greater.

All grains should commonly be ground for dairy cows. Grain should also be ground for beef cattle, with the exception that it does not pay to grind corn for them if pigs follow the cattle to salvage the unchewed corn kernels in the manure. All grains except corn and oats should be ground or crushed for horses and mules. In general, sheep chew their feed the most efficiently of all the larger farm animals. As a result, there is generally no advantage in grinding grain or other seeds for them, except in the case of seeds that are unusually small or hard.

89. Fineness of grinding.—Grain should not be ground so fine that it is dusty and floury, but instead it should be ground only medium fine. Extremely fine grinding not only takes much more power and time, but it generally makes the grain less palatable and may actually reduce its feeding value.

In various experiments it has required only one-half as much power and sometimes even less, to grind grain to a medium fineness as to grind it into a fine floury meal.[1] It is shown in later chapters that in experiments with dairy cows, lambs, pigs, and hens, grain ground medium-fine has also had a higher feeding value than that ground more finely.

The cost of grinding is somewhat less when grain is merely cracked than when it is ground to a medium degree of fineness. However, the utilization of the cracked grain is enough lower to make medium-fine grinding preferable. When grain screenings, which consist to a considerable extent of weed seeds, are fed to stock, many of the smaller seeds may pass through the digestive tract unchewed and alive. Very fine grinding of such screenings is therefore desirable to prevent infesting the fields with weeds, through applying manure that contains live weed seeds.

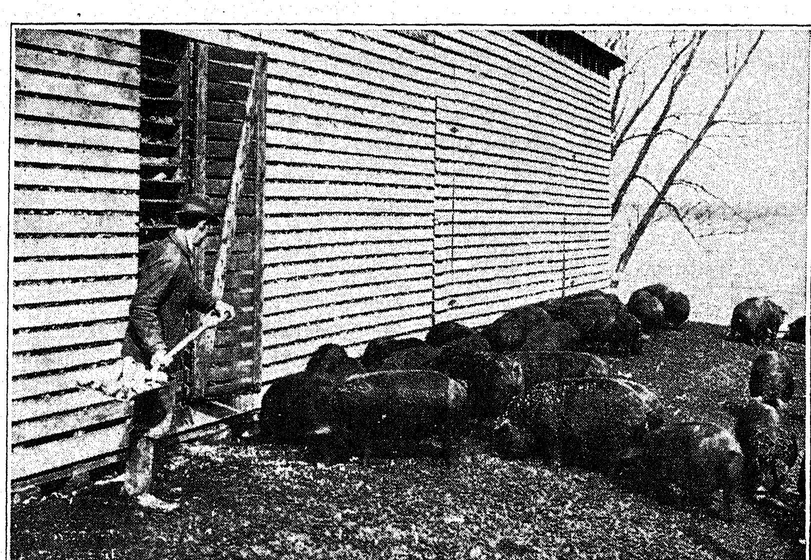
GRAIN SHOULD BE GROUND FOR DAIRY COWS

Dairy cows do not utilize whole grain efficiently, even corn and oats. It therefore pays well to grind grain for them.

90. Rolling or crushing grain.—The relative merits of rolling or crushing grain, compared with grinding it, have been much discussed. In fitting stock for

show on a full feed of concentrates, many stockmen prefer rolled or crushed grain in the mixture. This is because it is more bulky and may be less likely to cause digestive disturbances in such heavy feeding. Horsemen also often prefer rolled or crushed grain for feeding, as it is more bulky and may be less apt to cause colic.

For other classes of stock there is probably not much difference in the value of grain that has been rolled or crushed and that which has been ground.



THE SCOOP SHOVEL METHOD OF PREPARING CORN FOR PIGS

Up to the usual market weights, pigs utilize ear corn or shelled corn so efficiently that it does not pay to grind corn for them. (From Iowa Station.)

91. Pellets or cubes; crumbles.—Pellets or cubes are made by special machines from mixtures of concentrates or of concentrates and ground roughages, using pressure, usually with the addition of steam. Alfalfa meal is often pelleted to reduce bulk and expense in shipment. Sometimes pelleted feeds are broken coarsely by machine to form "crumbles." Much interest is currently being shown in hay pellets or "wafers." Such uses are discussed in the chapters dealing with the various classes of stock.

Pelleted feeds are especially adapted for outdoor feeding and for use as supplements for stock on pasture or range, as there is less wastage from wind and weather than when a ground mixture is fed. Since a certain weight of feed takes up less space when pelleted, animals may eat more feed in pelleted form than if the same mixture is fed ground.

Probably for this reason, broilers and young turkeys fed pellets may gain more rapidly and more efficiently than if fed the same mixture in mash form. The results have differed in the trials in which pellets have been compared with mash feeding for laying hens.

Growing and fattening pigs may gain appreciably faster and require less feed per 100 lbs. gain when self-fed a pelleted ration than when fed the same mixture as meal. The difference is greater when there is a large proportion of barley or oats in the mixture, than when corn, which is more concentrated, is the chief grain.

Several experiments have been conducted with fattening lambs to compare self-feeding a pelleted mixture of concentrates and ground hay with self-

feeding or hand-feeding the same kind of ration. Considering all trials so far conducted, feed consumption increased while both gains and feed efficiency improved. The increase in feed intake is largely responsible for the results. With cattle, more variable and less dramatic responses are usually observed. If roughage is of poor quality, pelleting gives better gains than if of good quality. A higher incidence of ruminal parakeratosis has been noted in lambs fed all-pelleted rations.

The cost of pelleted feed compared with ordinary rations largely determines the economy of this method of feeding.

Experiments have shown that a pelleted or coarse-textured concentrate mixture is no better for dairy cows than a mixture of ordinary fineness. (**1052**)

92. Chopping or grinding hay or other roughage.—In the case of hay, stover, and straw, there are no hard seed coats to be broken. Consequently, the ordinary chewing by livestock tears the forage into particles that can readily be penetrated by the digestive juices. Additional expense for chopping or grinding such roughage is therefore usually advisable only if it induces animals to eat coarse, stemmy portions that they would otherwise waste; or if they will consume a greater total amount of the roughage than when fed without the preparation.

For cattle, sheep, or horses, chopped hay is decidedly preferable to ground hay, and coarsely chopped hay is better than hay chopped fine. Not only are much less time and power required to chop hay than to grind it, but also chopped hay is much more desirable. Ground hay is apt to be less palatable to stock, and it is often so dusty that it is disagreeable to handle. In addition, the fine grinding of hay does not increase its digestibility, and may even decrease it.[2]

It is shown later that where a sufficiently large acreage of hay is made on a farm, handling it with a forage harvester, or hay chopper, is a very economical method. (**407**) By this means, hay may often be stored at no greater expense than for long hay. In chopping the hay, the machine should be set so as to chop the hay into as long lengths as is possible.[3]

In general, for dairy cows, beef cattle, sheep, and horses, it does not pay to go to extra expense to chop hay that is of good enough quality to be consumed with but little waste when fed long. If long hay is not fed in mangers that prevent undue waste, there may be considerable saving in chopping it. For example, in the West fattening lambs are commonly fed in open lots, and the alfalfa hay is frequently put on the ground, simply being rolled up against the fence of the feedlot. Under such conditions there is considerable wastage, and therefore chopping the hay and feeding it in a suitable rack or self-feeder makes a sufficient saving to justify the expense.

If hay is coarse and stemmy or otherwise of poor quality, there may be more advantage from chopping than with hay of good quality. Not only will the wastage be reduced, but also the stock will usually eat a greater amount of such roughage if it is chopped.

If one has an abundance of hay but it is of rather poor quality, it may be best not to chop it for dairy cows or for fattening cattle or sheep, but to feed very liberal amounts of the uncut hay. The stock can then eat the finer and more nutritious parts and leave the coarse stems, which have a very low feeding value. The stems can be used for bedding, or else given to animals that are not being fed for production, such as stock cattle being carried through the winter for fattening later, or to idle horses. It must be borne in mind that the chopping or grinding of roughage does not change the chemical composition of the stemmy portion at all, nor convert it into a high-grade feed.

In the case of corn or sorghum stover, it usually pays to cut or shred it to lessen the refuse, and also because the waste is then much better for bedding. Cut, shredded, or ground stover or fodder will heat or mold in storage unless thoroughly dry. For this reason, in humid districts such roughages frequently can-

not be kept for more than a few days, even in cool weather.

93. Mixing chopped or ground roughage with concentrates.—Claims have often been made that the value of a ration will be greatly increased if the roughage is chopped or ground and mixed with the grain or other concentrates. In spite of these claims, experiments have shown that such mixing of the feed does not generally increase its digestibility or its nutritive value. Farm animals have digestive systems which mix very thoroughly the feeds they eat.

However, in special cases the mixing of roughage with grain may be desirable from other standpoints. For example, horses are apt to have colic if fed a heavy grain, such as ground wheat or barley, as the only concentrate. Mixing with the ground grain a small proportion of a bulky feed, such as chopped or ground hay, ground oats, or wheat bran, will largely prevent the trouble. Fattening lambs which are self-fed a heavy feed, like corn, often suffer from digestive troubles. Mixing chopped or ground hay or some other bulky feed with the grain aids in preventing such difficulties.

It is highly desirable, when pigs are not on pasture, that they get some legume hay to provide vitamins A and D. If legume hay, even of good quality, is fed uncut in a rack, young pigs will frequently eat but little of it. It is therefore advisable to mix 5 per cent or more of chopped or ground legume hay in their concentrate mixture in order to force them to eat it.

Ground alfalfa meal or alfalfa leaf meal is also commonly included in poultry mashes as a vitamin supplement.

94. Cooking feed; soaking feed; feeding slop.—Many years ago it was firmly believed that cooking or steaming feed greatly increased its value. Careful experiments showed, however, that except in the case of the very few feeds mentioned later, such preparation does not increase the digestibility or feeding value. Instead there is a loss in most instances.

The only exceptions are a few feeds, especially potatoes, field beans, and soybeans, which are much better for feeding swine or poultry when the feeds are cooked. Soybean oil meal that has been properly cooked in the manufacturing process is also much superior to raw-tasting soybean oil meal for swine or poultry.

When grain with small or hard kernels cannot conveniently be ground or crushed, it may be advisable to soften it by soaking before feeding. Care should then be taken that such soaked grain does not become stale by long standing. Old corn often gets hard and flinty in summer and sometimes causes sore mouths in cattle or other stock if fed whole. It should then be ground or soaked.

Many farmers still feed ground grain and other meals to their hogs in the form of slop, believing that slop-feeding produces much better results than dry-feeding. However just as satisfactory results are generally secured when the same feeds are given dry, and much labor and bother are saved.

95. Fermenting, pre-digesting, malting, or sprouting feeds.—From time to time various processes of fermenting, malting, or pre-digesting feeds have been exploited by clever promoters. Claims have been made that these processes would save one-third to one-half the feed usually supplied livestock and would result in better production. Careful experiments have shown that these expensive methods of feed preparation do not cause any saving in feed or result in greater production.[4]

Some years ago, a method of sprouting grain for stock was advertised with extravagant claims of a great increase in feeding value. However, experiments showed that instead of a gain, there was a loss of 25 per cent of dry matter in the process.[5] Sprouted oats, which have sometimes been recommended as a cure for sterility in cattle, have not generally proven beneficial.

In Europe, methods of treating straw with caustic alkali to make it more digestible have sometimes been used during shortages of other feed. (**626**)

II. Factors Influencing the Nutritive Value of Feeds

96. Variations in the composition of feeds.—In computing rations for livestock, it is important to know how much the actual composition of any particular lot of a given feed may vary from the average given in Appendix Table I of this volume or in similar tables.

The following summary shows that the average figures for the composition of any feeding stuff are but approximately correct when applied to a particular lot of the feed. This is also true of any expression of its nutritive value, whether stated in terms of digestible nutrients or of net energy. In other words, different lots of any feed vary in feeding value, the same as different samples of coal vary in fuel value.

Owing to the expense of obtaining chemical analyses, it is out of the question for any but the most extensive feeders to have their particular feeds analyzed. With the cereals and the roughages most stockmen must therefore rely on that average given in tables of digestible nutrients or of net energy values which corresponds most closely in his judgment to the feed at hand.

In purchasing commercial concentrates it is now fortunately possible in most sections of the country to secure standard brands, whose composition is fully guaranteed by the manufacturer.

97. Differences in water content.—Obviously, the amount of moisture in grain or any other feed directly affects its nutrient content. Of the cereals, corn commonly varies most in water content. Therefore separate averages are given in Appendix Table I for dent corn of the various Federal grades, which are based largely on the water content.

Such roughages as corn fodder, corn stover, sorghum fodder, and sorghum stover also vary widely in water. For example, analyses of corn fodder and corn stover show a water content ranging from over 50 per cent in field-cured material in wet seasons, down to 10 per cent or less in arid regions, or when cured under cover in a dry season. Corn fodder having only 10 per cent of water supplies 80 per cent more nutrients per 100 lbs. than does corn fodder that contains 50 per cent of water! Separate averages are therefore given for very dry and for ordinary field-cured samples of these feeds in Appendix Table I.

98. Differences in roughage composition.—Roughages vary much more than most concentrates in composition. Their nutrient content may be greatly affected by the stage of maturity; the water content; the amount of plant food in the soil, especially phosphorus, nitrogen, and calcium; and in the case of hay or other cured forage, by weathering, shattering of the leaves, or leaching during curing.

On account of the great differences in the composition of the same variety of hay or other forage, separate averages are given in Appendix Table I for the various grades or qualities of the most important roughages, wherever sufficient data are available. The effects of various factors on the composition and feeding value of pasturage and hay are discussed in some detail in Chapters XIII and XIV.

It is there pointed out that there may be more actual difference in the feeding value of two lots of the same variety of hay than there is between hay of two entirely different kinds. For example, two loads of alfalfa hay may differ more in value than a load of alfalfa hay and another of timothy hay.

The supply of mineral nutrients in the soil not only affects the yield of crops, but also in the case of forages it may have very important effects on composition and nutritive value.[6] Also, proper fertilization may make pasture or hay more palatable to stock.[7] When only certain strips in a poor pasture are fertilized, stock will usually graze down the fertilized strips before they eat the rest of the forage. This may chiefly be because the fertilized plants are larger and more succulent.

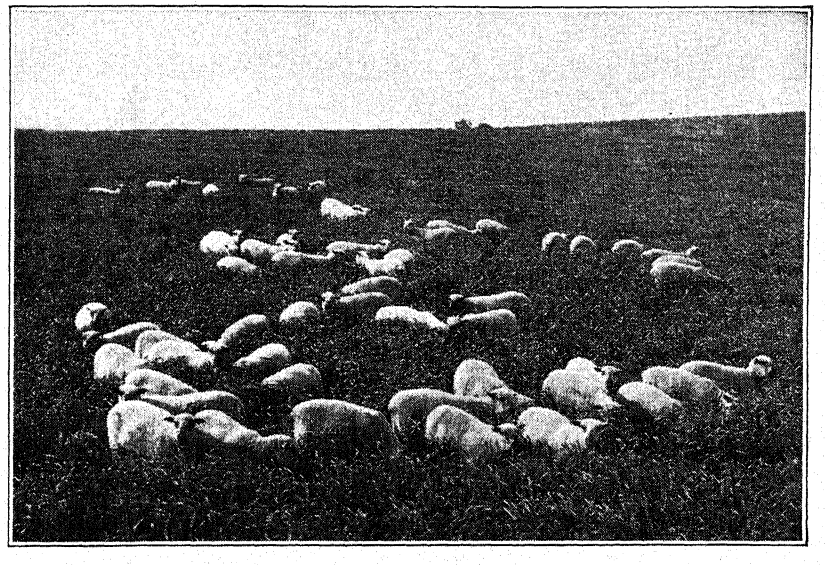
Pasturage or other forage grown on soil decidedly deficient in phosphorus is generally very low in phosphorus. Such forage may produce a serious deficiency in livestock, unless the animals are sup-

plied with a phosphorus supplement. The application of a phosphorus fertilizer to such soils will not only greatly increase the yield of forage, but it will also generally bring the phosphorus content of the forage up to normal levels.[8]

Deficiencies of calcium in forage crops are much less apt to occur than lacks of phosphorus. Even when grown on soil low in calcium, legume forage crops seem always to have a good content of calcium, though the yield may be greatly decreased by the lack of this mineral nutrient. However, the percentage of calcium in legume forage is generally higher when grown on calcium-rich soil than when raised on land deficient in calcium. The calcium content of non-legume forages is usually considerably less on calcium-poor soil than on soil containing plenty of calcium.

In a few areas the soil is so deficient in cobalt, copper, or iodine that very serious nutritional diseases are produced in livestock because of a lack of one or more of these "trace elements" in the forage. Such troubles can be prevented by the feeding of a mineral supplement, as explained in Chapter VI.

Where there is a border-line deficiency in the soil of cobalt or another trace mineral nutrient, liberal fertilization with ordinary fertilizers is apt to decrease the trace mineral content in the forage.[9] This is because the available amount of trace mineral is diluted in the much greater amount of forage produced.



ROUGHAGES VARY GREATLY IN COMPOSITION

The composition of a forage crop is greatly affected by the stage of maturity and also by the soil fertility. Young small-grain pasture, such as this, is rich in protein, on the dry basis, but hay made from small grains is relatively low in protein.

On soil very deficient in sulfur, fertilization with sulfur will not only greatly increase the yield of alfalfa and other legumes, but it will also improve the sulfur content and the feeding value of the forage.[10]

The protein content of forage crops is affected much more by the stage of maturity than by the supply of nitrogen in the soil. (359) At immature stages of growth most forage crops are much richer in protein than when more mature. Proper fertilization of pasture or hay land may greatly raise the protein content of the forage, because it increases the proportion of clovers or other leg-

umes. Also, liberal fertilization with nitrogen not only decidedly increases the yield of grasses on nitrogen-poor soil, but also improves the protein content. (372)

The increase in protein of grasses is greatest when nitrogen fertilizer is applied not only early in the spring but also later in the season. On soil low in nitrogen, liberal fertilization with nitrogen greatly increases the yield of corn and also improves the protein content of both the forage and the grain.[11]

It is fortunate indeed that proper fertilization not only increases the yield of pasture and other forage crops, but may also very decidedly improve the nutritive value. (383)

99. Differences in composition of grains and other seeds.—Climate and crop variety are the most important factors influencing the composition of the grains and other seeds. The yield of seeds may be greatly lowered because of a lack of plant food in the soil, but the percentage composition of the seeds is affected much less than with forage crops. Thus, a deficiency of phosphorus in the soil will reduce the percentage of phosphorus in grain much less than in forage crops.

It is pointed out in Chapter XX that the varieties of hybrid corn commonly grown are definitely lower in protein than the open-pollinated varieties grown some years ago. (682) This is apparently due both to inherited difference in protein content and to the greatly increased yield of hybrid corn. Unless hybrid corn is amply fertilized with nitrogen, the percentage of protein in the large yield of grain is lowered by a lack of nitrogen.

It is shown in Chapter XX that there is a wide variation in the percentage of hulls in oats, and therefore in the fiber content and the feeding value of the grain. Oats with shrunken kernels may be fully one-half hulls, while there should not be over 30 per cent of hulls in grain of good quality. Barley also varies in percentage of hulls, though not so much as does oats.

The protein content of wheat, oats, or barley is affected very materially by climate, and to a much smaller extent by the variety and other factors. It is pointed out in Chapters XX and XXI that these grains are especially low in protein when grown in certain districts of the Pacific Coast region. Separate averages are therefore given in Appendix Table I for these grains from that section of the country. The protein content of wheat may be appreciably increased by liberal fertilization with nitrogen.[12]

The composition of corn grain is affected by climate much less than that of the small grains, provided the crop matures. Fraps showed that under Texas conditions in seasons with abundant rainfall from January to June, the protein content of corn is apt to be slightly less than in dry seasons.[13]

Samples of the same variety of corn and wheat from the same region may vary 10 per cent and sometimes even more in content of protein or fat. There are much larger differences in the composition of different varieties of corn and wheat.

The nitrogen-free extract is less variable than the protein or the fat.

100. Differences in composition of by-product feeds.—Separate averages are given in Appendix Table I for the various grades of all important by-product feeds which vary to any marked extent in composition. Thus, averages are given for cottonseed meal, linseed meal, soybean oil meal, peanut oil meal, etc., containing various percentages of protein.

In accordance with the feeding-stuffs laws in the various states, the by-product feeds are sold with definite protein, fat, and fiber guarantees. (31) By comparing the guarantees for any lot of feed with the averages in Appendix Table I, one can find the approximate composition and the content of digestible nutrients in the feed. Feeds made by reliable manufacturers will usually have slightly more protein and fat and a little less fiber than stated in the guarantee. This practice is followed as insurance against any particular lot of the feed falling below the guarantee in protein or fat or coming above the guarantee in fiber.

Unfortunately, certain grades of meat scrap, tankage, and cottonseed meal seem commonly to have slightly less protein than is guaranteed by the manufacturer. (Appendix Table I)

In general, by-product feeds sold with a definite guarantee of composition will tend to vary decidedly less from the average for the particular grade of the feed than do the grains or the common roughages.

101. Effect of amount of feed eaten.—Experiments have shown that farm animals usually digest a slightly larger percentage of their feed when fed a scanty ration than when they receive a full ration that includes a liberal allowance of concentrates. Also, there is even a greater difference in the percentage utilization in the body of the nutrients from scanty and liberal rations.

When the ration contains a considerable proportion of roughage, the difference in digestibility of a liberal and a scanty ration is not large. In tests with cattle and sheep, from 3 to 9.5 per cent more of the dry matter in a mixture of roughage and concentrates was digested when the animals were fed only enough for maintenance than when they were fed liberally.[14] When fed hay alone or such a combination as hay and roots, ruminants may digest a full feed as completely as a scanty ration.[15]

It might seem at first that the feeding of a scanty ration would result in more efficient production. However, an animal can use for the production of meat, milk, or work only the nutrients consumed in excess of the amount needed for the maintenance of its body. Therefore, if it is fed scantily, it will have available for production only a small proportion of the total feed eaten.

For example, a good dairy cow that is well fed needs about one-half her feed merely to maintain her body. She uses the remaining one-half for milk production. If she is fed only two-thirds as much feed, she will digest the scanty ration somewhat better, but she will still need about as much feed as before to maintain her body. Therefore she will probably have available for milk production only 30 per cent or less of the total feed she eats. It is of great importance in practical stock feeding that this factor usually more than offsets the increased digestibility and percentage utilization of a scanty ration.

Even if a slight reduction from full feeding causes a trifle better percentage utilization of the ration, other factors usually make liberal feeding more profitable. Just as in the case of a factory which is run below its normal capacity, the overhead costs in stock feeding are greater when an animal is producing at a low rate. For example, the expense per pound of product for labor, for housing, and for interest on money invested are all much higher when the rate of production is low.

In certain cases it may be advisable for other economic reasons to feed animals less grain or other concentrates than normal. Thus, when grain is very high in price in comparison with hay or other roughage, fattening cattle may return the most profit if their allowance of grain is reduced and they are fed all the roughage they will eat.

Again, it may sometimes be most profitable to fatten meat animals more slowly than usual, so as to have them ready for market at a time of the year when prices are usually high. These various matters are discussed in detail in the chapters of Part III.

It is shown in Chapter XXXIV that leaner carcasses and higher-quality bacon are produced if pigs are fed during the finishing period a somewhat limited amount of feed or else a ration higher than normal in fiber.

In most of the digestion trials that have been conducted with cattle and sheep to determine the digestibility of various feeds, the animals have not been fed all they would eat. The amounts of feed have been restricted somewhat, as otherwise they might not eat all the feed that was weighed out, which would make it impossible to find the digestibility of the ration that had been fed. For this reason the average digestion coefficients given in Appendix Table I are undoubtedly slightly too high to show

the actual digestibility of feeds by liberally-fed dairy cows, fattening cattle, or fattening lambs.[13] Consequently, such stock will not secure from the various feeds quite so much digestible protein and total digestible nutrients as shown in Appendix Table I.

The differences are only slight, however, and these facts have been fully taken into consideration in the recommendations made in the Morrison feeding standards. Therefore rations for dairy cows, fattening cattle, and fattening lambs which are computed according to these standards and from the averages in Appendix Table I will be entirely satisfactory in practical livestock feeding.

102. Effect of nutritive deficiencies.—Any marked nutritive deficiency may seriously reduce the digestibility of the food. In the case of ruminants this is partly due to the fact that the cellulose-digesting bacteria in the rumen need ample supplies of nutrients for effective development and activity. As emphasized in Chapter II, cellulose digestion in ruminants is much lowered if there is a lack in the food of protein or a protein substitute, or of the essential minerals. (**45**)

Digestibility is also much reduced when a ration has too little protein in proportion to the amounts of easily digested carbohydrates. This is of great importance, for it is one of the reasons why a protein-poor ration is inefficient.

One of the reasons why ruminants digest such rations poorly is that when there is a large proportion of easily digested carbohydrates, the bacteria in the rumen attack the more readily available starch or sugars instead of the resistant cellulose. Not only is the digestibility of the fiber consequently lowered, but also that of the protein and nitrogen-free extract, for the unattacked cellulose cell walls protect the proteins and carbohydrates contained therein from the action of the digestive juices. If a sufficient amount of protein-rich feeds is added to balance the ration, the bacteria seem to be so stimulated that they attack the fiber of the food again.

The extent of this loss is shown in a compilation made by the author of the results of digestion experiments with cattle or sheep in which kafir grain was fed in properly-balanced rations and in rations too low in protein. When fed in unbalanced rations, 100 lbs. of kafir supplied only 58 per cent as much digestible protein and 57 per cent as much total digestible nutrients as it did when fed in a balanced ration. Similar data might be given for the other grains.

In the case of mature fattening cattle or mature work animals, the actual needs of protein for body repair or the making of new protein tissues are very small, as is explained in later chapters. However, because of this depression of digestibility, it is economical to feed such stock somewhat more protein than is needed for their theoretical requirements. These facts are fully taken into consideration in the Morrison feeding standards. (Appendix Table III.)

The depression of digestibility caused by a lack of protein occurs with ruminants when the nutritive ratio is wider than about 1 : 8 or 1 : 10, but with swine the nutritive ratio may be even wider before digestibility is affected.

The decrease in the digestibility of protein on a ration low in protein is more apparent than real. The addition of non-nitrogenous food to a ration causes a greater excretion of protein in the feces. The amount of this additional loss depends chiefly on the amount of food added. This larger excretion of protein may consist chiefly, not of undigested protein, but of protein that has been assimilated and then excreted as a waste. However, from the practical standpoint, the additional wastage of protein is just as truly a loss as though it represented solely a decrease in actual digestibility.

In conducting digestion trials to determine the digestibility of feeds that are rich in easily-digested carbohydrates, but low in protein, it is exceedingly important to add a sufficient amount of protein supplement to the ration to prevent any depression of digestibility. This is well shown in experiments by Holdaway and associates of the Virginia Station.[16] In previous digestion trials made by various investigators, the protein in apple-pomace silage, which is very low in protein and very high in easily-digested carbohydrates, was apparently not digested to any

appreciable extent. On the other hand, in the Virginia tests when a sufficient amount of protein supplement was included in the ration, along with the pomace silage, 37 per cent of the protein in the silage was digested, and the digestibility of the nitrogen-free extract was also slightly increased.

103. Effect of proportion of other nutrients.—The addition of more than a small amount of molasses or of sugars in some other form to a well balanced ration for ruminants may slightly decrease the digestibility, especially of protein.[17] This is apparently because the bacteria in the rumen tend to attack the sugar instead of the fiber and other more resistant carbohydrates in the rest of the ration. The results secured from the addition of molasses to practical rations for various classes of stock are discussed in detail in Chapter XXIII.

The addition of fat to a ration does not generally increase the digestibility of the other constituents.[18] It has been found that feeding cattle more than 1 lb. fat per 1,000 lbs. weight or feeding pure fat or oil in unemulsified form may cause digestive disturbance. The effects of different amounts of fat in rations for the various kinds of stock are discussed in later chapters.

The addition of salt to a ration does not affect digestion, even when a large amount is added.[19] The salt needs of farm animals are treated in later chapters.

In a New Hampshire experiment the addition of an excessive amount of ground limestone lowered the digestibility of silage for dairy heifers, but a normal amount did not have this effect.[20]

The addition of dilute acids, such as lactic acid (the chief acid in sour milk and in silage) or of sulfuric acid, does not influence digestibility. This is important because silage contains considerable free acid.

Adding fiber to a ration reduces the apparent digestibility of the protein, but not its actual digestibility.[21] (**102**)

104. Associative action of feeds.—In some digestion experiments certain feeds have been more digestible when fed in balanced rations with certain other feeds than when fed in other well-balanced combinations.[22] The term "associative action" has been applied to these effects.

Opinions differ as to the importance of such differences in practical stock feeding when well-balanced rations are fed, because some investigations have shown no differences of this kind, or only very slight ones.[23]

105. Effect of other factors in feed.—If green forage is cured without waste and in a manner to prevent fermentation, the mere drying does not appreciably lower its digestibility. Ordinarily, however, losses of some of the finer and more nutritious parts occur in curing forage. Also, fermentation and leaching cause changes which lower digestibility and decrease the content of nutrients. (See Chapter XIV.) Furthermore, more energy is required in masticating dry forage and passing it through the digestive tract than in the case of green forage. These facts explain why green forage is somewhat more digestible and commonly gives better results than dry forage. The long storage of fodders, even under favorable conditions, decreases both their digestibility and palatability. In the making of brown hay, as is pointed out in Chapter XIV, heavy losses of nutrients occur.

A comparison of the digestion coefficients for various kinds of silage with those for the green forages from which the silage was made, shows that ensiling tends to decrease rather than increase the digestibility. The exceedingly favorable results from silage feeding are therefore due to the palatability of the silage, to its beneficial effect on the health of the stock, and to the fact that less feed is wasted than when dry fodder is fed.

If a feed is heated to an unduly high temperature in a manufacturing process, the digestibility may be considerably decreased, especially that of the protein. The value of grain damaged by fire will depend on the extent of the damage.[24] Badly charred grain has little value, while that damaged by smoke may be nearly equal to sound grain, except in palatability.

Grain damaged by frost is usually higher in fiber than normal grain and is consequently less digestible and of somewhat lower feeding value.[25]

The digestibility of a few feeds is increased markedly by cooking, especially for swine and poultry. As is pointed out in later chapters, this is the case with beans, soybeans, and potatoes.

106. Effect of miscellaneous factors.—Cattle and sheep digest most kinds of feed equally well, but such low-grade roughages

as straws, which are very high in fiber, are digested somewhat better by cattle than by sheep.[26] In Pennsylvania experiments there was no marked or consistent difference in the digestibility of the same mixture of hay and concentrates by dairy cows and by sheep, when they were fed at a similar level above their maintenance requirements.[27]

Horses and pigs digest less fiber than do ruminants, in whose paunch the coarse feeds undergo special preparation and digestion. The richer the feed, the more nearly do the digestive powers of horses approach those of other farm animals. Swine digest concentrates fully as well as do ruminants, but make only small use of the fiber. Poultry digest fiber to a much less extent than do ruminants.

In general, age does not, in itself, influence digestibility, though young farm animals cannot utilize much roughage until their digestive tracts are developed. The digestive power of old animals is often indirectly impaired by poor teeth, which make the proper chewing of their food impossible.

Breed does not influence digestibility. Individual animals may, however, show considerable difference in their ability to digest the same ration, though ordinarily the digestibility of a given ration by different animals of the same kind will not vary by more than 3 to 4 per cent.

Neither the frequency of feeding, the time of watering, nor the amount of water drunk (within reasonable limits) appears to influence digestibility.[28] Moderate exercise tends to increase digestibility, but excessive work lowers it.[29]

The flow of saliva and the other digestive juices is checked by fright. On the other hand, kind treatment and palatability of food should favorably influence digestion. Under skillful care animals show remarkable relish for their food, and it is reasonable to conclude that better digestion results.

QUESTIONS

1. What general principles determine whether or not it will pay to grind or crush a certain kind of grain for a particular class of stock?
2. To what degree of fineness should grain ordinarily be ground for stock feeding?
3. What are pelleted or cubed feeds and when may they be advantageous?
4. Discuss the chopping of hay or other roughage for livestock; the grinding of hay or other roughage.
5. Under what conditions may it be wise to mix cut or ground roughage with concentrates?
6. Discuss the cooking of feed for cattle; for swine.
7. When would you soak feed for stock or feed slop to pigs?
8. What have experiments shown concerning any benefit from fermenting, predigesting, or malting feeds, or sprouting grain?
9. Give an example of the effect of a difference in water content on the value of a feed.
10. What factors affect the composition of roughages?
11. Discuss the effect of soil fertility and of climate on the composition of grain and other seeds.
12. Which tend to vary more in composition—by-product feeds of guaranteed composition or grains and common roughages?
13. Discuss the effect of the amount of feed eaten on its utilization. Should dairy cows or fattening stock be fed scantily, in order that they will digest their rations most completely?
14. What is the effect upon digestibility of having too little protein in a ration?

REFERENCES

1. Vestal and Hienton, Ind. Rpt. 1929 and mimeo. rpts.; Fenton and Logan, Kan. Engineering Expt. Sta. Bul. 27; Martin and Roberts, Kan. Exten. Bul. 87; Silver, Ohio Bul. 490; Bohstedt, Roche, Fargo, Rupel, and Duffee, Wis. Bul. 421.
2. Forbes, Fries, and Braman, Penn., Jour. Agr. Res., 31, 1925, pp. 987–995; see also: Swanson and Herman, Mo., Jour. Anim. Sci., 11, 1952, pp. 688–692; Murdoch, Miller, Blosser, and Erb, Wash., mimeo. rpt.; Ambo and Chiba, Bul. Nat. Inst. Agr. Sci., Japan (G), 1952, No. 4, pp. 99–105.
3. Fischer, Duffee, and Bohstedt, Wis. Bul. 449.
4. Musschl, Ackerson, and Borchers, Nebr. Rpt. 60; Perkins and Monroe, Ohio Bimo. Bul. 134; Monroe and Hayden, Ohio Bimo. Bul. 150; Hayden and Monroe, Ohio Buls. 446, 470; Bohstedt, Bell, and Gerlaugh, Ohio Special Cir. 10; Morrison, Humphrey, Fuller, Roche, and Wolberg, Wis. Bul. 396; Rupel, Roche, Bohstedt, and Fuller, Wis. Res. Bul. 102; Canada Dept. Agr. Bul. 96; Lawes and Gilbert, Rothamsted Memoirs, Vol. IV.
5. Rpt. Nat. Institute Res. Dairying, Reading, England; Bul. Agr. Sci. Pract., England, 26, 1935, pp. 62T–86T; see also: Bartlett, Cotton, Henry, and Kon, Jour. Dairy Res., England, 9, 1938, pp. 273–309; Leitch, Imp. Bur. Anim. Nutr., Great Britain, Tech. Commun. 11; Brown, Agr. Gaz., N.S. Wales, 48, 1937, pp. 121–125, 187–190; Paterson, West of Scotland Agr. Col., Farmer and Stock-Breeder and Agr. Gaz., 50, 1936, p.

1725; Müller, Switzerland, Archiv. Geflügelk., 17, 1952, pp. 16–27; Hennaux, Antoine, Seilleur, and Lecomte, France, Bul. Inst. Agron, Gembloux, 20, 1952, pp. 72–81.
6. Excellent reviews on this subject are: Beeson, Botanical Review, 12, 1946; pp. 424–455; Beeson, U.S. Dept. Agr. Misc. Pub. 369; Southern Coop. Series, Bul. 36.
7. Funchess, Ala., Better Crops with Plant Food, Feb., 1953; Staten, Okla. Tech. Bul. T-35; Williams, MacLeod, Morrell, and Price, Tenn. Rpt. 1948.
8. Ittner, Rendig, Ayers, and Weir, Cal. Agr., 7, 1953, No. 8; Davis et al., Fla. Rpt. 1949; Webb et al., Ill., Jour. Anim. Sci., 7, 1948, pp. 159–169; Doty, Jackson, and Quackenbush, Ind. Rpt. 1950; Hanway, Stanford, Dumenil, and Pierre, Iowa Rpt. 1949–51, Part 1; Millar, Mich., Jour. Amer. Soc. Agron., 30, 1938, pp. 507–513; Rost, Burson, and Hammers, Minn. Farm and Home Sci., 5, 1947, No. 1; Matrone et al., N.C. and U.S.D.A., U.S.D.A. Tech. Bul. 1086; Duncan and Sanders, Tenn. Rpt. 1945; Wash. Sta. Cir. 103.
9. Keener, Allen, Morrow, and Percival, N.H. Bul. 402; see also: Price, Linkous, and Hill, Va. Tech. Bul. 117.
10. Weir and Rendig, Cal., Jour. Anim. Sci., 11, 1952, pp. 780–781; Rendig, Weir, and Inouye, Cal. Agr., 9, 1955, No. 6; Bledsoe and Killinger, Fla. Rpt. 1950; Hauge, Mertz, Kingsley, and Needham, Ind. Rpt. 1949; Ore. Buls. 477, 491.
11. Harshbarger et al., Ill. Bul. 577.
12. Id. Bul. 276; Nebr. Rpt. 63; Peterson, Utah Bul. 353; see also: Moseman, U.S.D.A., Science News Letter, July 11, 1953.
13. Fraps, Texas Bul. 422.
14. Mumford, Grindley, Hall, and Emmett, Ill. Bul. 172; Mitchell, Hamilton, et al., Ill., Jour. Agr. Res., 45, 1932, pp. 163–191; Eckles, Mo. Res. Bul. 7; Jordan, N.Y. (Geneva) Bul. 141; Perkins and Monroe, Ohio Bul. 376; Forbes, Braman, Kriss., et al., Penn., Jour. Agr. Res., 37, 1928, pp. 253–300; 40, 1930, pp. 37–78; Schneider and Ellenberger, Vt. Bul. 270; Watson, Woodward, Davidson, Muir, and Robinson, Sci. Agr., Canada, 17, 1936, pp. 11–21; 19, 1939, pp. 622–651; 20, 1940, pp. 458–469; Watson, Davidson, Kennedy, and Sylvestre, Sci. Agr., Canada, 31, 1951, pp. 113–119; Honcamp and Koch, Germany, Land, Vers. Stat., 96, 1920, pp. 45–120.
15. Watson, Muir, and Davidson, Sci. Agr., Canada, 15, 1935, pp. 476–487; Watson, Woodward, Davidson, Robinson, and Muir, Sci. Agr., Canada, 18, 1938, pp. 586–605; Hall, Duncan, and Huffman, Mich., Amer. Soc. Anim. Prod., Proc. 1939.
16. Holdaway, Ellett, Eheart, and Miller, Va. Tech. Bul. 32; see also: Holdaway, Ellett, and Eheart, Va. Tech. Bul. 38.
17. Mitchell, Hamilton, and Haines, Ill., Jour. Agr. Res., 61, 1940, pp. 847–864; Hamilton, Ill., Jour. Nutr., 23, 1942, pp. 101–110; Snell, La. Bul. 266; Briggs and Keller, Okla., Jour. Agr. Res., 60, 1940, pp. 65–72; Williams, Penn., Jour. Dairy Sci., 8, 1925, pp. 94–104.
18. Lucas and Loosli, N.Y., Jour. Anim. Sci., 3, 1944, pp. 3–11; Swift et al., Penn., Jour. Anim. Sci., 6, 1947, pp. 432–444.
19. Cardon, Ariz., Jour. Anim. Sci., 12, 1953, pp. 536–540.
20. Colovos, Keener, Teeri, and Davis, N.H. Bul. 409.
21. Titus, New Mex. Bul. 153.
22. Forbes, Bratzler, and French, Penn. Bul. 391; Forbes, Swift, et al., Penn. Bul. 452; Cowan, Penn. Bul. 553.
23. Mitchell, and Hamilton, Ill., Jour. Nutr., 22, 1941, pp. 541–552; Weber, Smith, and Hughes, Kan. Rpt. 1946–1948; Richardson, Kan. Cir. 308; Watson et al., Sci. Agr., Canada, 20, 1939, pp. 175–192; 22, 1942, pp. 561–570; 30, 1950, pp. 456–466, 476–482; 31, 1951, pp. 25–31.
24. Whiting and Bezeau, Canadian Jour. Agr. Sci., 34, 1954, pp. 635–638.
25. Whiting and Bezeau, Canadian Jour. Agr. Sci., 34, 1954, pp. 624–634.
26. Jordan and Staples, S.D., Jour. Anim. Sci., 10, 1951, pp. 236–243; Cippolloni, Schneider, Lucas, and Pavlech, W. Va. and N.C., Jour. Anim. Sci., 10, 1951, pp. 337–343.
27. Forbes, Bratzler, Black, and Braman, Penn. Bul. 339.
28. Balch, Balch, Johnson, and Turner, British Jour. Nutr., 7, 1953, pp. 212–224.
29. Schneider and Ellenberger, Vt. Bul. 262.

CHAPTER V

PROTEINS—FATS—CARBOHYDRATES

I. Proteins in Livestock Feeding

107. Importance of proper amount and kind of protein.—It has long been known that all animals must receive in their food at least a certain minimum *amount* of protein. More recently, investigations have shown that for man and for such animals as swine, poultry, dogs, and rats, the *quality* or *kind* of protein is fully as important as the amount. The quality of protein in rations is therefore discussed in detail in the pages that follow.

The general requirements of protein for various body functions are considered in Chapters VIII to X, and further information on the requirements of each class of stock is presented in Part III. The amounts of digestible protein advised by the author for the different classes of stock are shown in the feeding standards presented in Appendix Table III.

In estimates of the minimum amounts of protein required by farm animals, such as are given in feeding standards, it is assumed that typical rations are fed, which provide protein of average quality. If the protein is of superior quality, a somewhat smaller amount will suffice. On the contrary, if the protein is of inferior nutritive value, a greater amount will be needed, and even then the production of the animals will generally be lowered, in spite of the liberal supply of the inefficient protein.

It has been explained in Chapter I that *crude protein,* called merely *protein* generally in this book, includes all the nitrogenous compounds in feeds. (18) It is determined by finding the percentage of nitrogen and multiplying this by 6.25. (24) To distinguish the substances which are actually protein from the simpler nitrogenous compounds, the term *true protein* is used.

108. Effect of an excess of protein. Protein-rich feeds are generally more expensive than those which are low in protein but rich in carbohydrates and fat. In practical livestock feeding we are therefore commonly interested only in knowing the minimum amounts of protein that farm animals require for the best results.

However, protein-rich feeds may sometimes be cheaper than carbohydrate-rich feeds. This is often the case, for example, with cottonseed meal in the South and with alfalfa hay in certain sections of the West. The question then arises as to how much protein farm animals can be fed without injury. This problem is of especial interest because an excessive amount of protein throws an increased load on the liver and kidneys, which must excrete the surplus nitrogen.

Experiments have shown that there is no danger from feeding farm animals a considerably larger amount of protein than they actually require. As shown in Chapter XXII, dairy cows have been fed cottonseed meal, which is very rich in protein, as the only concentrate without injurious results, if they had plenty of vitamins and minerals. Pigs have made normal gains and remained in good health on rations containing 30 to 42 per cent of total protein.[1]

It is shown in Chapter II that although protein has considerably more gross energy than do carbohydrates, it does not furnish any more net energy. (73) For this reason, when a larger amount of a protein-rich supplement, such as soybean oil meal or cottonseed meal, is fed than needed to balance the ration, the excess amount is worth no more and often a little less than corn or other grain.

It was formerly believed that an excess of protein would increase the heat production in the body, and thus lower

the net energy value of an entire ration. Protein-rich diets were therefore considered unsuited for hot weather. However, in actual experiments an excess of protein has not had this effect.[2] The excess amount of nitrogen was merely excreted in the urine, and did not increase the heat production.

In the case of young animals that are growing and fattening, the feeding of a ration very high in protein may tend to make them grow more rangy and to lay on less fat than if fed rations lower in protein.

and thus be used in place of carbohydrate food.

Certain of the simpler amino acids can be made in the bodies of animals, either from some of the more complex amino acids or by combining ammonia or other simple nitrogenous compounds with organic acids formed from other food nutrients. However, the body is not able to synthesize several of the more complex amino acids in the body tissues, and these must therefore be provided from the proteins of the food. In certain cases the body may be able to make small amounts of an amino acid, but not enough to permit rapid growth.

QUALITY OF PROTEIN MAY BE AS IMPORTANT AS THE AMOUNT

Animals need not only plenty of protein in their food, but also protein of the right kind or quality. The pig on the left received plenty of protein, but his ration consisted of only grain and grain by-products, supplying protein of poor quality. The pig on the right, which is of the same age, received a ration of grain plus skimmilk, which supplied protein of good quality. (From Hart, Wisconsin Station.)

109. Essential amino acids.—It has been explained in Chapter I that proteins are exceedingly complex substances, made up of 24 or more different amino acids. In the digestion of food, the proteins are split into these amino acids, which are absorbed from the digestive system and enter the blood stream.

The mixture of amino acids is then carried in the blood to the various body tissues, where each organ or tissue takes the quantities of the different amino acids that it needs for its repair or functioning. As has been explained previously, the nitrogen is split off from the excess amino acids by the liver and this waste nitrogen is excreted in the urine by the kidneys. (51) The non-nitrogenous residue from the amino acids can be converted into glucose and glycogen

The amino acids which cannot be made in the body from other substances, or which cannot be made in sufficient amounts, are called the *essential amino acids.*

Protein for the growth of protein tissues of the body or for such purposes as the production of milk cannot be made by an animal unless it has an adequate supply of each of the essential amino acids. A shortage of a single one will limit the use of all the others, and therefore reduce the efficiency of the entire ration.

For example, let us suppose that an animal is building protein tissues that contain 5 per cent of a certain essential amino acid. However, the mixture of

amino acids furnished by the food contains only 1 per cent of this same amino acid. Five times as much food protein will then be required to form a given amount of body protein, as would be needed if the food protein supplied the same percentage of this essential amino acid as there was in the body tissue.

The nutritive value of a protein is not affected if it is deficient in one of the non-essential amino acids. Thus, casein, the chief protein of milk, is a protein of high nutritive value. Nevertheless, it has very little glycine, which is the simplest in structure of all the amino acids and is readily made in the body from other sources by most animals.

110. Determining which amino acids are essential.—Many experiments have been conducted with laboratory animals fed rations of highly purified nutrients to determine which of the amino acids are essential. In some of these investigations the only source of protein has been purified protein or artificially digested protein, which was known to be lacking in one or more amino acids. In other experiments mixtures of pure amino acids have replaced all the food protein.

The pioneer investigations to determine which amino acids are essential for animals were by Rose at the University of Illinois with young rats. Later studies have been conducted with human beings, with chicks, with young pigs, and with dogs.

In the experiments by Rose it was found that the following 10 amino acids are essential for the growth of rats: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.[3]

A supply of arginine in the food is not needed for maintenance or for slow growth of rats, but they cannot synthesize this amino acid rapidly enough in their bodies to permit normal growth. Cystine, one of the two sulfur-containing amino acids, was formerly considered essential, but it has been found that cystine is not needed if the ration has enough methionine, the other sulfur-containing amino acid. Methionine is essential for growth. It can be replaced partially, but not entirely, by cystine.

Recently, the amounts of nearly all of the essential amino acids required by chicks and young pigs have been ascertained in careful experiments, which are summarized in Chapters XXXIV and XXXVI.

111. Differences in amino acid requirements.—The requirements of animals for the various amino acids differ, depending on the kind of animal and also on body function. Certain amino acids that are necessary for growth are not essential for merely maintaining a mature animal. For example, it has already been mentioned that arginine is necessary for normal growth of rats, but not for mere maintenance or for slow growth. Apparently, some of the other amino acids which are needed by rats for growth are not required for maintenance.

This can be explained by assuming that in the small daily breakdown and repair which takes place in the protein tissues of the body, entire protein molecules are not destroyed, but only certain groups split off. Then, the needs for maintenance would not involve building entire proteins, but only replacing these more simple groups.

The amino acid requirements of swine and dogs are similar to those of rats. Chicks need not only the 10 amino acids that are essential for rats, but also glycine (the simplest amino acid) and probably also glutamic acid.

So far is is known, the amino acid requirements for milk production resemble those for growth.

With the exception of glycine (the simplest amino acid), the amino acids can be in two forms—the L- form and the D- form. In proteins, only the L-forms occur, and in the case of most of the amino acids, these are the only form which can be utilized by animals. The D- form of tryptophan can be used to a limited extent.

Certain of the amino acids have been synthesized chemically, and some of these are now being made commercially. In most cases, these are mixtures

of both forms of the amino acid. The use of the synthetic amino acids as supplements to rations is discussed in the chapters dealing with the respective classes of farm animals.

112. Requirements of ruminants and horses much more simple.—Fortunately, ruminants and horses have much more simple requirements for protein than do rats, dogs, pigs, chickens, or man. This is because the bacteria and other micro-organisms which are so important in the digestion of fiber by these animals are able to use for their food very simple nitrogenous compounds, which the animals could not themselves use at all.

The bacteria build these simple forms of nitrogen into complete proteins in making the cells of which they are composed. Then, further on in the digestive tract of the ruminant, these bacterial cells are digested, and the protein that has been made by the bacteria is thus made available to the animal.

Experiments have proved that all 10 essential amino acids can be thus made by the rumen bacteria from simple forms of nitrogen in the food.[4] Therefore the bacterial protein may provide all of the essential amino acids, even though they are lacking in the feed which the ruminant eats. A similar action occurs in the caecum and colon of the horse.

For this reason, in the feeding of dairy cows, beef cattle, sheep, and horses, much less attention need be given to the kind or quality of protein in the ration than is needed in the feeding of swine or poultry. As is shown later, even such simple substances as urea can be used satisfactorily to replace a considerable part of the protein in feeding dairy cattle and beef cattle. For the first few weeks after birth, before the rumen has developed sufficiently, young ruminants need protein of good quality that supplies the essential amino acids.

Another reason why the quality of protein is usually not of major importance in feeding dairy cattle (except young calves raised on a minimum amount of milk) and in feeding beef cattle, sheep, and horses, is that a large part of their rations generally consists of roughage. The quality of protein in good pasturage, hay, or silage is superior to that in the cereal grains, which often form most of the rations for swine and poultry.

113. Other nutritive essentials in protein.—In some of the nutrition experiments with rats and mice, used as test animals, growth has not been so rapid on mixtures of pure amino acids, substituted for protein, as on a diet containing natural protein. It therefore seemed that some other necessary factor besides the known essential amino acids was supplied by food protein.[5] This factor has been called "strepogenin," and may have been certain peptides, which are combinations of amino acids that are simpler than protein.

In recent Wisconsin experiments, however, entirely normal growth of rats was secured on a diet in which an improved mixture of pure amino acids furnished all the nitrogen.[6] On the other hand, in trials with chicks and laying hens, it has not been possible to secure satisfactory results on a mixture of pure amino acids as a substitute for all the protein.[7] The question as to whether food protein supplies some other essential than amino acids is therefore still unsolved.

114. Quality of protein; supplementary effect.—Many of our common feeds contain too small amounts of one or more of the essential amino acids to produce good results when used as the only source of protein for such animals as swine or poultry. On the other hand, a few feeds, such as milk, eggs, and meat, supply the various amino acids in very nearly the proper proportions for complete utilization.

Feeds or rations that furnish insufficient amounts of any of the essential amino acids are said to have *protein of poor quality*. Those which have the proper proportions of all of the essential amino acids are said to supply *protein of good quality*.

Fortunately, the feeds that have proteins of poor quality are not all deficient in the same amino acids. For this

reason the proteins in two feeds, each of which furnishes poor-quality protein when fed alone, may supplement each other in a very important manner. For example, the quality of protein in corn grain is poor because corn protein is low in lysine and tryptophan, which are two of the essential amino acids for such animals as swine and poultry. As is shown in later chapters, tankage, a meat by-product, is an effective supplement to corn in feeding swine and poultry. This is true even though the quality of protein in tankage is low when it is fed as the only source of protein. (Much of the protein in tankage consists, not of meat tissue, but of protein in gristle, connective tissue, and bones, which is of poor quality.)

Another good illustration of the supplementary effect of proteins is the manner in which milk corrects the deficiencies in the proteins of the grains. Milk is able to correct the lacks in grain protein, because it is rich in lysine, which is low in all the grains. Also, it is rich in tryptophan, which is deficient in the protein of corn and some other grains.

The manner in which milk makes good the deficiencies in corn protein is shown by Wisconsin experiments in which young pigs were fed rations containing protein from various sources. When pigs were fed only wheat, corn, or oat grain, they stored in their bodies but 23 to 28 per cent of the total protein in their feed.[8] On the other hand, when skimmilk was the sole source of protein, they were able to store 66 per cent of the protein supplied by the milk.

A mixture of one-third each of corn, wheat, and oats was only a trifle better than any one of the cereals alone, for they are all deficient in lysine. However, when pigs were fed 1.3 lbs. of skimmilk to each pound of corn, they made 62 per cent of the total protein in their feed into body tissues. The milk was thus rich enough in lysine and tryptophan to make the combination of corn and milk nearly as efficient as milk, which is often called the ideal food.

This well shows that it is unnecessary for each feed in a ration to furnish protein of high quality. All that is needed is a sufficient amount in the entire ration of each of the essential amino acids.

115. Effect of excessive heating; of long storage.—Too much heat in a manufacturing process injures the quality of protein in feeds by destroying or making unavailable certain amino acids, especially lysine, tryptophan, arginine, and histidine.[9] It is pointed out in Chapter XXII that although the value of soybean oil meal for non-ruminants is decidedly improved by thorough cooking, too high heating injures it. (793) Also, the flame-drying of such a by-product as fish meal decreases the value of the protein, in comparison with drying at a lower temperature. (917) In the commercial drying of grain, too high a temperature reduces the protein value.[10]

The decrease in value of grain damaged in elevator or other fires will differ widely, depending on the actual amount of damage by heat or charring, or by water with subsequent molding. In some cases such grain may be worth nearly as much as sound grain, and in others it may have little value.

The storage of well-dried corn or wheat for as long as 2 to 3 years did not appreciably lower the value of the protein in Illinois tests, but storage for only a year definitely reduced the digestibility and availability of the protein in soybean seed.[11] In trials by the United States Department of Agriculture with various lots of corn stored as long as 6 years, in some cases the efficiency of the protein was much reduced, but not in others.[12]

116. Time factor in protein supplementation.—Recent studies indicate that for certain animals the feeding of a protein supplement some hours after the other feed is eaten may reduce the effectiveness of the supplement.[13] This could be explained as follows: If the animal is fed corn every day, but is fed a protein supplement only every other day, there will be in its body a deficiency of lysine and tryptophan during the day in which no supplement is fed. The other amino acids resulting from the di-

gestion of the corn can therefore not be used effectively and they cannot be stored in the body until the next day. There is consequently an increased wastage of amino acids through deamination. (51)

Experiments with young rats have shown that delaying for several hours the feeding of an amino acid which was deficient in the diet, decreased the formation of protein tissue in the body. This time factor may be less important in the feeding of livestock, because of the longer time the food remains in the digestive tract. In a Nebraska experiment a 24-hour delay in giving the protein supplement to young pigs fed corn did not decrease the growth or the formation of protein tissue.[14] A still longer delay in feeding the supplement was appreciably detrimental.

However, it is shown in Chapter XXVIII that in Kansas trials the gain was much less when young beef cattle being wintered on mature range pasture were fed a double allowance of protein supplement every other day to save labor, instead of the normal amount each day.

117. Amino acid content as a measure of value.—Until recently, it was not possible to find accurately the percentages of the various amino acids in feeds, because the carbohydrates interfered with the determinations. Information could therefore be secured only on the amino acid content of pure proteins, such as corn zein, which had been extracted from the grain and purified.

Fortunately, methods have now been developed for determining the content of the different amino acids in entire feeds. After the protein in the feed is broken down as completely as possible by digestion with acid or otherwise, the percentages of the various amino acids are found. For most of the amino acids, the rapid microbiological method is used, in which the amount of an amino acid is determined by the rate of growth of certain bacteria which require the particular amino acid.

As yet, the results secured by various investigators differ appreciably, but information has been obtained which shows approximately the content of the different essential amino acids in some of the most important concentrates. But little such data is available for roughages, except for alfalfa meal.

Appendix Table X states the approximate percentage of certain amino acids in some of the most important feeds, so far as data are available. Such information is helpful in formulating efficient rations for pigs and poultry, as it shows how feeds can be combined to meet the known requirements for the different essential amino acids.

118. Measuring the values of protein in feeds.—Because of the difficulty in determining accurately the amounts of each of the essential amino acids in a feed, the information concerning the nutritive value of various feeds as sources of protein has been gained chiefly through practical feeding experiments. A great number of experiments of this kind are summarized in Parts II and III of this book.

In such investigations the animals are fed rations in which various protein supplements or mixtures of feeds are directly compared, and the production on each ration carefully determined. Care must be taken to make sure that the experimental rations fully meet all the requirements for energy, minerals, and vitamins. Otherwise, the utilization of the protein will be decreased by a lack of other nutrients. It is just as important that no more protein be fed than is actually needed, or some will be wasted.

In experiments in which it is desired to compare the value of the protein in various rations, each ration must have the same percentage of protein. This is because the percentage efficiency with which protein is used depends on the level of protein in the ration.

This principle is of great importance in practical feeding experiments. If two protein supplements are being compared which contain considerably different percentages of protein, correspondingly less of the supplement richer in protein should be used.

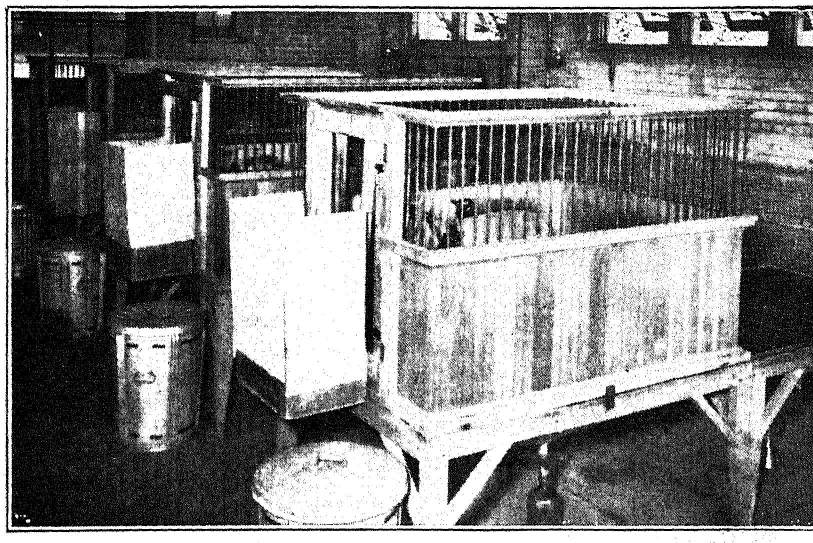
If enough of the low-protein supple-

ment is fed to balance the ration in protein content and the same amount of the high-protein supplement is included in the other ration, it should be evident that there will be an excess of protein in the latter ration. Part of the high-protein supplement will then be wasted, so far as its use as a protein supplement is concerned. On the other hand, if just enough of the high-protein supplement is used to balance one ration and no more of the low-protein supplement is included in the other ration, the latter will not supply enough protein for optimum results.

Therefore, whenever this fundamental principle is neglected, either one or the other of the rations will be made less efficient than it should be, solely because the experiment was not properly planned. Unfortunately, this simple principle has not been considered in certain of the comparisons that have been made of protein supplements.

119. Biological values; other measures of protein quality.—The most common laboratory method of measuring the nutritive value of the protein in a ration is to determine the *biological value*. This is the percentage of the digested protein that is used for both maintenance and growth. In such an experiment, the feces and the urine voided by the experimental animal are carefully collected and analyzed, so as to find the amount of protein stored in the body.

In this method a protein that was used with perfect efficiency for maintenance and growth would have a biological value of 100 per cent. Few feeds even approach this theoretical efficiency, and a value of 90 per cent or more proves that the protein in a feed has an unusually high efficiency. Biological values of 75 to 90 per cent indicate that the protein is considerably better than average.



DETERMINING NUTRITIVE VALUE OF PROTEIN IN RATIONS

Experiments are being conducted with lambs in these metabolism cages to determine the nutritive value of the protein in different rations. The feed is accurately analyzed and weighed, and all feces and urine are collected and analyzed. (From Cornell University.)

In such metabolism experiments the results can also be stated in terms of the percentage of total protein or of digestible protein that is stored by the animal. In similar tests with lactating animals, one can find the percentage of food protein that is secreted in the milk.

The "gross protein value" method has been used at the Washington Station to find the relative value, in comparison

with casein, of various protein supplements for balancing a base diet made up of farm grains, mill feeds, and alfalfa meal.[15]

In the carcass analysis method, used sometimes in experiments with laboratory animals, the amount of protein stored in the body on each ration is determined by analysis of the carcasses of animals fed the ration, in comparison with the analyses of similar animals slaughtered at the beginning of the trial.

A chemical method sometimes used to measure the quality of protein in various protein supplements is to digest the feed in a solution of pepsin or other enzymes and hydrochloric acid.[16] The portion not digested is considered valueless. This method seems to be useful for fish meals and packing-house by-products, but is less reliable for other feeds.

120. Protein of cereal grains and by-products.—Since the cereal grains and their by-products form such a large part of the concentrates fed farm animals, it is essential that the nature of their protein be thoroughly understood. When fed as the only source of protein, the grains all fall decidedly below such a food as milk in quality of protein.

The results have differed considerably in the experiments to compare the quality of protein in the various grains, when furnishing all or nearly all the protein in the ration. Generally, the protein of corn has been less efficient for growth than the protein of barley, oats, or wheat. Also, corn generally has considerably less protein than these other grains. All of the grains are low in lysine, and corn and milo are deficient in tryptophan as well.

When the cereal grains have been fed to pigs, chicks, or rats as the only source of protein, the biological value of the protein has usually ranged between 60 and 70 per cent when the rations have had 8 to 10 per cent protein. In comparison with this, the protein in milk has generally had a biological value of 85 to 90 per cent or more. Highly-milled flour made from the cereals, such as patent wheat flour, has somewhat poorer quality protein than the entire grain.

No good stockman feeds his animals grain alone. In livestock feeding the important question is therefore how the deficiencies of the protein of the grains can be corrected by proper combination with other feeds. It has been previously shown that milk effectively makes good the lacks in the protein of grain. (114) Other protein-rich feeds that efficiently supplement the protein of the grains are fish meal, meat scrap, tankage, soybean oil meal, and peanut oil meal. These and other protein supplements are discussed later in this chapter, and further information concerning the manner in which they supplement the grains is given in the chapters of Part III.

The germs of the cereal grains furnish protein of better quality than the rest of the kernels. Also, the bran layers of wheat have better protein than the endosperm portion. Therefore wheat bran and wheat middlings supply better protein than the entire wheat grain.[17] Likewise, corn oil meal (made from the corn germs) has better protein than the entire corn grain or than corn gluten feed. Similarly, the protein in rice bran and rice polish is of much better quality than the protein in the entire rice kernel.[18]

Though these particular cereal by-products have better protein than the entire cereal grains, none is satisfactory as the only protein supplement to grain for feeding swine or poultry. For the best results it is necessary to combine them with such feeds as milk, fish meal, meat scrap, or soybean oil meal, which more effectively correct the deficiencies of the cereal protein.

Corn gluten feed and corn gluten meal resemble corn grain in deficiencies in quality of protein. For swine or poultry these corn by-products should be combined with protein supplements that correct these deficiencies.

121. Feeds of animal origin.—The values of the various protein supplements of animal origin are discussed in detail in Chapter XXIII. As has been emphasized previously in this chapter, milk pro-

tein makes good the deficiencies of the cereal proteins in a very complete manner. Casein, which forms over three-fourths of the protein in milk, is but slightly inferior to the entire mixture of proteins that milk contains.

Lactalbumin, or milk albumin, which forms most of the rest of the milk protein, is of even higher value than casein. The protein of whey is chiefly lactalbumin. It is therefore not surprising that whey is very effective in correcting the deficiencies in the protein of the cereal grains, even though whey has only a small percentage of protein on the dry basis.

The proteins of eggs, meat, and fish are also of unusually high nutritive value, a fact that is of great importance in human nutrition. The protein of eggs is equal or superior to that of milk, and meat and fish rank but slightly below in quality of protein. Animal tissues that consist mostly of gristle and connective tissue are of much lower value than muscle or most glandular tissue, such as liver or kidney.

For swine and poultry feeding, the meat and fish by-products are popular protein supplements. Meat scrap and tankage correct the deficiences of the protein of the grains, but are less effective single protein supplements to the grains than are soybean oil meal or fish meal. The protein value of much of the meat scrap and tankage now made seems to be lower than that made years ago, presumably because it is more largely composed of gristle and connective tissue. (**902**) Fish meal consisting mostly of fish heads has a lower value than that made chiefly of muscular tissue.

Blood meal of the usual kind is not high in digestibility, and the protein is apparently not of as high nutritive value as that of meat scrap or tankage.[19]

122. Protein of legume seeds.—The proteins of the various legume seeds and their by-products differ to a surprising degree in nutritive value. For the feeding of swine and poultry, we can give top rank among protein-rich feeds of plant origin to the protein of soybean oil meal that has been properly cooked in the manufacturing process. Indeed, such soybean oil meal equals or comes close to milk in making good the deficiencies in the proteins of the grains.

The protein of raw soybeans is of much lower value for swine, poultry, or such laboratory test animals as rats, because thorough cooking is required to make the methionine and cystine in soybeans fully available to these animals. However, if the cooking is too severe, the nutritive value may be decreased. Cooking soybeans does not appreciably improve the value of soybean protein for such ruminants as cattle over 1 year of age or sheep.

For swine not on pasture, especially young pigs, and also for poultry, rations consisting of soybean oil meal, grain, and grain by-products are generally improved somewhat by the addition of a small amount of meat scrap, tankage, fish meal or skimmilk.

It is shown in Chapter XXII that the value of peanut oil meal as a protein supplement equals or closely approaches that of soybean oil meal. Cooking improves peanut protein less than soybean protein.

Peas are a very satisfactory feed for livestock, except for the fact that they are usually expensive. However, the protein of peas does not supplement that of the cereals as completely as does that of soybean oil meal, because of a deficiency of methionine. (**855**) Therefore in poultry feeding peas cannot be used to replace as large a proportion of the animal-protein supplements as is possible with soybean oil meal.

Most beans and also cowpeas and lentils have protein of much poorer quality than does soybean oil meal. Also, beans are utilized very poorly by swine and poultry unless they are thoroughly cooked.

The values of other legume seeds are discussed in Chapter XXII.

123. Protein of other concentrates.—Detailed information is given in the various chapters of Part II concerning the many other protein supplements available for stock feeding. On account of the importance of linseed meal and

cottonseed meal, the nutritive value of their protein is of especial interest. These are excellent supplements for dairy cattle, beef cattle, sheep, and horses.

For swine or poultry, the protein of linseed meal does not effectively supplement the protein of the grains, probably because it contains less lysine than does soybean oil meal. Therefore for swine or poultry linseed meal should be used in combination with such a supplement as soybean oil meal, fish meal, meat scrap, or tankage, which supplies more lysine. (829) It is shown in Chapter XXII that for another reason than quality of protein linseed meal is not satisfactory as any important part of a ration for poultry. (836)

Ordinary cottonseed meal can be used in only very limited amounts for swine or poultry, because of the gossypol content. (811) Recently, methods have been developed for producing de-gossypolized cottonseed meal, which can make up a larger part of their rations. (812) Even this cottonseed meal should, however, be fed in combination with such protein supplements as fish meal, soybean oil meal, meat scraps, or tankage.

Coconut oil meal is not satisfactory as the only protein supplement to the cereal grains for feeding swine or poultry.

Dried brewers' yeast and other yeasts, which are rich in B-complex vitamins, are also rich in protein and can be used as protein supplements in stock feeding. However, yeast should not be used as the only protein supplement to grain for swine or poultry.

Distillers dried solubles are also very rich in B-complex vitamins and rich in protein, but the protein is not of good quality for poultry or swine. It did not supplement corn protein in Indiana tests, because it was low in the same amino acids.[20]

Nuts, except peanuts, are rarely used for stock feeding. It is of interest to note, however, that although nuts are rich in protein, the protein of most nuts was decidedly inferior to that of meat in Illinois tests.[21]

124. Protein of forage crops.—There is but little exact information concerning the value of the protein in pastures, hay, and silage, for swine and poultry or for other animals that need protein of high quality. However, practical feeding experiments show that the protein of most first-class roughages is at least of fairly good quality, and that it corrects to a considerable extent the deficiencies in the proteins of the grains.

Pigs on excellent pasture, such as alfalfa, clover, or rape, make reasonably good growth when fed only corn or other grain, plus a mineral supplement. However, such a ration is too low in amount of protein for the most rapid growth, especially of young pigs. Also, the quality of the protein can be made still better by adding to the ration such a protein supplement as skimmilk, meat scrap, or fish meal.

Similarly, for poultry excellent pasture, such as Ladino clover, other clovers, or alfalfa, greatly reduces the need for high-quality protein supplements, such as meat scrap or milk by-products.

125. Protein in non-legume forage.—From the excellent growth made by young cattle, sheep, and horses on good grass pasture, we can conclude that there is no deficiency for such animals in the quality of protein supplied by most kinds of young grass.

Some experiments to compare the value of the protein in grasses and other forages have been conducted with rabbits and guinea pigs, used as laboratory test animals. Both rabbits and guinea pigs are able to digest such roughage fairly efficiently through bacterial action in the digestive tract, though less completely than do cattle or sheep. In Arkansas tests with guinea pigs there was not much difference in the biological value of the protein of most kinds of young grass and of legume forage, but the protein in the legume forage was digested to a slightly greater extent.[22] In Florida experiments the quality of Bermuda grass protein for rabbits was nearly as good as that of a clover-grass pasture.[23]

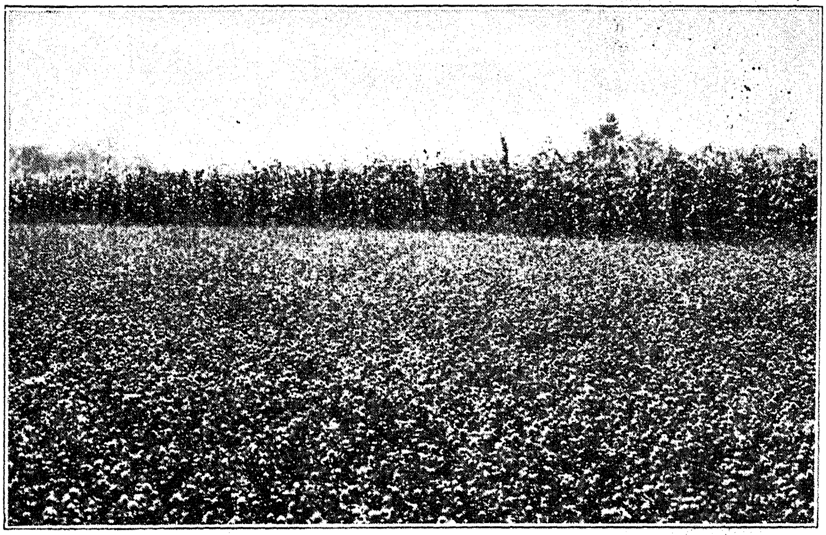
In Canadian tests with rabbits the

protein of mixed grasses from a fertilized plot was of higher value than that of grass from an unfertilized area.[24] Also, the protein in young timothy was of decidedly higher value than that of young reed canary grass.

Other experiments have indicated that although the amount of protein in corn silage and wheat straw is low, the quality of protein in this small amount of protein is satisfactory for lambs.[25]

for dairy cows, beef cattle, sheep, and horses. Red clover hay likewise furnishes protein of good quality for these animals, but it is somewhat lower than alfalfa in amount of protein.

Investigations have shown that legume hay even provides protein of good quality for ruminants when it is fed as the only source of protein. This was proved in metabolism experiments with growing lambs at the New York (Cor-



LEGUME FORAGE INSURES GOOD PROTEIN FOR RUMINANTS

A fine crop of red clover in the foreground, with corn in the background. Such a combination as clover or alfalfa hay and corn grain provides good quality protein for ruminants.

126. Legume forage insures good-quality protein for herbivora.—One of the exceedingly important facts in livestock feeding is that legume forages admirably supplement the grains in feeding dairy cattle, beef cattle, sheep, and horses. This is emphasized in Chapter XVI.

First of all, legume forages are rich in protein. Also, the combination of grain and legume forage furnishes protein of very satisfactory quality for these animals. It is shown in later chapters that merely an abundance of well-cured alfalfa, soybean, or cowpea hay, fed with farm grain and without any high-protein supplement, makes a satisfactory ration

nell) Station.[26] When growing lambs were fed either alfalfa hay or red clover hay as the sole source of protein in a ration supplying plenty of carbohydrates and fat, the biological value of the protein was high. Indeed, the protein of the legume hay or of legume hay and corn grain was just as efficient as the protein of soybean oil meal or of dried skimmilk. Similar results were secured in Missouri experiments with dairy heifers.[27]

127. Quality of protein in feeding cattle or sheep.—A question of much importance is whether or not it is necessary to give any consideration to quality of protein in the practical feeding of dairy cattle, beef cattle, or sheep. Detailed in-

formation concerning this problem in feeding each of these classes of stock is given in the respective chapters of Part III.

In general, it seems safe to conclude that for cattle or sheep there is not apt to be any deficiency in the quality of protein when any considerable part of the roughage consists of legume forage. If enough legume hay or even mixed hay high in legumes is fed, good results can be secured when the only protein supplement is such a feed as corn gluten meal or corn gluten feed, both of which have proteins of rather poor quality. If only non-legume roughage is fed, especially that of poor quality, then the kind of protein supplied by various protein supplements may sometimes be important.[28]

A possible explanation of such differences with good-quality roughage and poor roughage may be the following: When all of the roughage is of poor quality, the bacterial fermentation in the rumen may be so changed that there is less formation of good-quality protein by the bacteria from the nitrogenous compounds in the feed.

In raising dairy calves chiefly on milk substitutes, attention must be given to the quality of protein in the ration for the first few weeks, until the rumen has developed enough for the calf to consume and utilize considerable roughage.

128. Amino acid supplements.—If a ration for pigs or poultry is deficient in one of the essential amino acids, the lack can be corrected by including a feed that has a good supply of this amino acid, or else by adding a small amount of the pure amino acid. The amino acid requirements of pigs and poultry and the ways in which a lack of essential amino acids can be corrected by a suitable protein supplement are discussed in Chapters XXXIV and XXXVI. Commercial products are also on the market, prepared from natural feeds, which are rich in certain of the essential amino acids.

Through the recent commercial production of some of the essential amino acids synthetically, it has become possible to use a pure amino acid to supplement a ration which has too small an amount of that amino acid. Thus far, methionine and lysine are the only essential amino acids produced at a sufficiently low cost to make such use practical. Methionine is available at approximately $1.50 per pound, and synthetic lysine is about $4.50 per pound. Other amino acids are much more expensive.

The use of synthetic methionine in rations for pigs and poultry is treated in Chapters XXXIV and XXXVI. Such supplementation with methionine has thus far been used chiefly in rations for chicks and turkey poults.

129. Urea as a protein substitute.—With our present livestock population, insufficient amounts of protein supplements are available to balance properly the rations for all the farm animals. It is therefore fortunate that many thousands of tons of urea, which can be used as a partial protein substitute for certain classes of stock, are manufactured each year from the nitrogen of the air for use in industry and agriculture.

Each pound of urea, which is a very simple nitrogenous compound, contains as much nitrogen as 2.9 pounds of protein. To reduce the trouble from caking in storage, a small amount of other material is mixed with the feed urea to give a product containing as much nitrogen as though it had 262 per cent of protein.

Numerous investigations have shown that when urea is added to a suitable ration for ruminants, the bacteria in the rumen can convert it more or less completely into protein in their cells during the fermentation which occurs normally in the rumen digestion.[29] The urea is first changed rapidly into ammonia in the rumen, and this is combined with non-nitrogenous compounds in the building of the bacterial protein. Further on in the digestive tract, the bacteria are digested, and the protein is thus made available to the animal. (44)

The conversion of urea into protein is not efficient when the ration does not have a readily available supply of energy for the bacteria, or when urea is

added to a mixture that is already fairly high in protein.

When urea is added to a concentrate mixture which has the usual amount of cereal grains, the conversion into protein is satisfactory, as the starch in the grain furnishes plenty of energy for the bacteria. The conversion of urea into protein is poor when urea is added to hay alone, without any concentrates. Also, the conversion is not satisfactory when urea is added to molasses and such roughage as grass hay. However, urea can be converted into protein effectively when the concentrate mixture contains a good supply of grain, along with some molasses. For sheep, which have a high sulfur requirement in wool production, the utilization of urea may be increased if sulfur is added to a ration which is low in this mineral.

Too large an amount of urea in a concentrate mixture may make it unpalatable, and animals may be poisoned if they consume more than a certain amount of urea. Therefore not more than 2 to 3 per cent of urea should be included in the total concentrates fed. Also, urea should not form more than 5 to 10 per cent of protein supplemental mixtures or pellets, or the palatability may be much decreased.

Urea must be mixed very thoroughly and carefully in a mixture, to prevent any animal from getting a dangerous amount. Deaths of stock have been caused in a few instances by mixed feeds, containing urea, which were not prepared with sufficient care.

It must be borne in mind that urea furnishes no energy to an animal, while the common protein supplements furnish both protein and energy. Therefore when protein-rich feeds cost but little more than the farm grains, the use of urea is uneconomical. For example, even if the nitrogen in urea is used as efficiently as the nitrogen in a protein supplement, it will require about 14 lbs. of urea plus 100 lbs. of corn or other grain to replace 100 lbs. of soybean oil meal.

If a ration already has enough protein, there will be no advantage in adding urea to it. Thus, it is shown in Chapter XXV that for dairy cows a concentrate mixture having 16 to 18 per cent protein supplies plenty of protein for feeding with corn silage and good mixed hay containing at least one-third legumes. (1017) There will be no benefit from adding urea to such a concentrate mixture, so as to increase the protein equivalent to 20 per cent or more.

The use of urea as a protein substitute for dairy cattle, for beef cattle, and for sheep is discussed in the chapters dealing with these classes of stock. Urea has given the most satisfactory results when it has replaced not more than one-fourth to one-third the protein in a ration, and when there was considerable grain in the mixture. It has usually not been an effective protein substitute when used without grain, but mixed only with molasses or alfalfa meal. Urea has been used chiefly in formula feeds (commercial mixed feeds) for dairy cattle and beef cattle. It has also been a fair substitute for part of the protein in rations for pregnant and lactating ewes, but in some of the experiments with fattening lambs it has not been an effective protein substitute.

Urea has little or no value as a protein substitute for swine or poultry, or for dairy calves before the rumen is well developed.[30] However, a properly mixed urea-containing feed will not poison these animals if they chance to eat some of it.

Differing from certain advertising claims made for urea, feeding experiments have shown that even with poor roughage, rations containing urea generally give no better results than when all the protein is supplied by natural feeds.

130. Urea-treated silage.—In some experiments urea has been added to green forage as it was ensiled, to increase the protein value of low-protein silage, such as corn or sorghum.[31] Beef cattle being wintered do better on such silage than on corn or sorghum silage with no protein supplement, but may not gain quite so well as on normal silage and a protein supplement.

In some tests the addition of urea to

silage has reduced the palatability, and in a Florida trial a considerable part of the added nitrogen was lost from the silage as ammonia or by leaching.

131. Other protein substitutes.—By adding ammonia to certain low-protein feeds, ammoniated products have been made, which might serve, like urea, as partial protein substitutes. These have included ammoniated cane or corn molasses, ammoniated citrus pulp, ammoniated beet pulp, ammoniated condensed distillers molasses solubles, and ammoniated furfural residue.

In recent New York experiments the nitrogen in ammoniated molasses, ammoniated citrus pulp, and ammoniated distillers molasses solubles was much less available to rumen bacteria or to steers than the nitrogen of urea.[32] Similar results were secured with ammoniated molasses in recent Ohio tests.[33]

In some feeding experiments *ammoniated molasses* has given results similar to those with urea.[34] However, in other trials cattle and sheep have had extreme nervous symptoms after receiving ammoniated cane molasses only a few days, acting crazy.[35] Death has sometimes followed unless the feed was discontinued.

Ammoniated condensed distillers molasses solubles has been a fairly satisfactory substitute for part of the protein supplement.[36]

Ammoniated citrus pulp was less palatable than plain citrus pulp to beef cattle, and produced less gain than cottonseed meal.[37]

In an English test *ammoniated beet pulp* was worth less than ordinary beet pulp,[38] and in a Colorado trial it had no advantage over alfalfa hay as a source of protein for fattening cattle.[39]

Ammoniated furfural residue in one experiment decreased the gain of beef cattle when replacing half the cottonseed meal in the ration.[40]

By heating urea, *biuret,* a less soluble condensation product, is formed. Since this is less toxic than urea if a large amount is consumed, its value as a protein substitute is being tested. In recent trials lambs gained slightly less with biuret as a protein substitute than with urea.[41]

In an experiment with dairy heifers another nitrogen compound, *dicyanodiamide,* produced slightly smaller gains than did soybean oil meal.[42]

II. Fats in Livestock Feeding

132. Functions of fats.—It has been shown in Chapter I that several groups of substances besides the true fats are included in the ether extract, or so-called "fat" of feeds and animal tissues. (13–14) Though present in only small amounts, certain of these substances are very important in animal nutrition.

For instance, vitamin A, carotene, and vitamin D, which are discussed in Chapter VII, are soluble in fat solvents and are therefore included in the ether extract. Cholesterol and the phospholipids, which are essential constituents of the body, are other important components of ether extract, though usually present in very small amounts. Vitamins E and K are likewise soluble in ether and are thus included in the ether extract.

In seeds most of the ether extract is true fat. On the other hand, in forage crops more than one-half of it may consist of other compounds, especially chlorophyll, which apparently has no food value to animals. The digestion, absorption, and utilization of fat in the body have been explained in Chapter II. (47, 51)

The fat in foods serves as a source of energy, the same as the carbohydrates. Also, body fat or the fat in milk can be formed from the fat in the feed. Fat is a much more concentrated source of energy than the carbohydrates, for digestible fat furnishes about 2.25 times as much energy per pound as is contained in digestible carbohydrates. For this reason, a concentrate mixture very low in fat is generally lower in total digestible nutrients than one having more fat.

Fat is not only a concentrated source of energy and of body fat or milk fat, but it also has other functions. It aids in the absorption from the food of vitamin A and especially of carotene, and

may help in the absorption of calcium. Experiments have also shown that the net-energy value of a ration is decreased if it is unusually low in fat. (78)

Fat forms a considerable part of the food of suckling animals. For example, fat forms as much as one-third of the dry matter of cow's milk. It is pointed out in Chapter IX that for very young calves, especially for those that are not vigorous, milk that is not unduly rich in fat is better than very rich milk. (269)

For certain animals, fats that have a high melting point are less digestible and of less value than fats which have a lower melting point. However, for farm animals, except possibly poultry, there does not seem to be such a difference.[43]

The effect of the kind of fat in the ration upon the character of body fat or milk fat made by animals is discussed in Chapter IX and in the chapters of Part III.

133. Need of fat by farm animals.—The question as to whether farm animals require a certain minimum amount of fat in their rations for optimum results is now of greater importance than formerly, because of the wide use of the solvent process of extracting fat very completely from such oil-rich seeds as soybeans and from some by-products high in fat.

It has been shown in previous chapters that carbohydrates can serve not only as the source of energy in the body, but also as the source of body fat and milk fat. However, experiments summarized in the chapters dealing with the various classes of stock have proved that young calves, lambs, pigs, and chicks need a certain minimum amount of fat for growth and health.

Experiments with dairy cows reviewed in Chapter XXV also show that the yield of milk is reduced when the concentrate mixture is too low in fat. (**1020**) In these experiments and in trials with pigs, the difference in value per 100 lbs. of rations low in fat and moderate in fat was greater than the difference in energy value as ordinarily computed. In other words, the additional amount of fat was worth more than 2.25 times as much as an equal weight of digestible carbohydrates.

Experiments with laboratory animals fed diets containing almost no fat have shown that rats, mice, and dogs require for growth and even for health small amounts of certain unsaturated fatty acids, such as linoleic acid, which are present in most natural fats. These are called the essential fatty acids.

Whether farm animals need these fatty acids (linoleic, arachidonic, and linolenic) is still unknown. In New York experiments young calves could not live on a fat-free diet, but the fat deficiency was corrected by including 2 per cent of hydrogenated coconut oil, which contains no unsaturated fatty acids.[44] This indicates that the deficiency was not a lack of essential unsaturated fatty acids.

134. Adding fat to rations.—Except under special conditions, carbohydrates furnish energy for farm animals more cheaply than do fats. Therefore the ability of livestock to utilize increased amounts of fat in their rations has not until recently been of practical importance.

During the past few years, there has been a large surplus in this country of by-product animal fats, produced in the meat and rendering industries. As a result, the prices of these tallows and greases have fallen to levels that make their use in livestock feeds practical. This surplus has come about chiefly because of the advent and wide use of detergents in the soap industry, and the desire of consumers for meat cuts from which more of the surplus fat has been trimmed.

In the manufacture of formula feeds, or mixed commercial feeds, the addition of 1 to 2 per cent or more of such fats reduces dustiness and may improve the color, texture, and palatability of the feed. Because fat is a lubricant, adding it makes the feed mixture less abrasive to machinery, such as mixers, conveyors, and scales. This lubricating quality of added fat also appreciably increases the capacity of pelleting machinery. In this country, a small amount of such animal fat is now added to some

of the commercial alfalfa meal to reduce dustiness and improve the color.

To prevent the development of rancidity, it is essential to use fat to which an approved antioxidant, or stabilizer, has been added in proper amount. When a stabilized fat is added to a feed mixture, there is a tendency for the loss of vitamin A and of xanthophyll during storage to be reduced.[45] On the other hand, the use of unstabilized fat in a mixture increases the loss of vitamin A and vitamin E.

Animal and vegetable fats seem to be equally effective additions to feeds, but ordinarily by-product animal fats are much cheaper than such plant fats as soybean or cottonseed oil. Hydrogenated fats, or stearic acid, which have a melting point above body temperature, are not well utilized, at least by poultry. Also, a fat that is very solid at ordinary temperatures does not reduce dustiness and improve appearance like liquid or softer fats.

The experiments in which by-product fats have been added to rations for the various classes of stock are summarized in the chapters dealing with the different kinds of farm animals.

135. Does the fat of milk have special value?—It is well known that one of the great values of milk as a human food and as a food for all young mammals is the high vitamin A value of the fat. Many experiments have been conducted in an endeavor to find whether the fat of milk has other special values, most of the tests having been with young rats started on the experimental diets after weaning. In such studies care is taken to supply in all diets an abundance of vitamin A and other vitamins that may be furnished by butterfat. In some of the investigations the young rats have made better growth on diets containing milk fat, when lactose was the carbohydrate food. However, in other tests there has been no difference in the results from milk fat and other fats.

In experiments in which dairy calves have been raised from birth on semi-purified diets or on milk replacers containing ample vitamins, the calves grew poorly and usually died when fed ordinary plant oils, such as soybean oil or cottonseed oil as a substitute for milk fat. However, when lard or homogenized hydrogenated plant fat was used, the growth was nearly normal, though sometimes slightly less than on milk fat. (1114)

These results indicate that for very young animals various kinds of fat may differ decidedly in value, even when an abundance of vitamin A is provided from other sources.

III. Carbohydrates in Livestock Feeding

136. Value and functions of various carbohydrates.—The carbohydrates in feeds differ greatly in digestibility and nutritive value, as has been shown in previous chapters. Starch and the sugars are readily digested and have a high feeding value. Cellulose and the other very complex carbohydrates are digested only through the bacterial action that occurs in the rumen of ruminants, in the caecum and large intestine of horses, and to a much less extent in the large intestine of other animals. By this means ruminants, such as cattle and sheep, and also horses are able to digest and utilize the fiber of feeds fairly well, though it has a much lower value for them than starch. Swine or poultry can make very little use of fiber. Lignin is digested to only a very small extent, even by ruminants.

It has been shown in Chapter II that in the process of digestion starch is changed to glucose. Compound sugars are also converted almost entirely into glucose or other simple sugars and absorbed into the blood in this form. In the bacterial digestion of fiber the chief useful products are organic acids, largely acetic acid. Experiments have shown that these organic acids are absorbed and used in the body the same as glucose.

Since carbohydrates form about three-fourths of the dry matter in most plants, they are the chief source of energy and heat for farm animals. Most of the energy for muscular work thus comes from the carbohydrates in the food. It is

also shown in later chapters that the carbohydrates are the chief source of body fat and an important source of the fat in milk.

So far as is known, in ordinary rations the value of the carbohydrates in various feeds generally depends on the extent to which they are digested and on the net energy they furnish. Thus, the value per pound of starch and of the various sugars is usually about the same, while fiber has a much lower value, even for ruminants.

Especially for young animals, milk sugar (lactose) seems to increase the assimilation and use of calcium and phosphorus, probably because of its influence on the type of bacterial growth in the intestines. Lactose tends to produce an acid type of fermentation and to prevent putrefaction. However, too large a proportion of lactose, as when there is too much dried whey in a ration, may produce diarrhea. (**896**)

137. Molasses.—Molasses, consisting chiefly of sugars, may sometimes be very desirable in stock feeding, as it increases the palatability of feeds that might not otherwise be well-liked. For example, stock will clean up low-grade hay better if diluted molasses is sprinkled over it. It has been shown in the preceding chapter that the addition of a large amount of molasses to a ration may decrease its digestibility. (**103**)

The use and value of molasses for the various classes of stock are discussed in Chapter XXIII.

QUESTIONS

1. Is it generally dangerous to feed considerably more protein than needed?
2. Explain what is meant by an essential amino acid.
3. How can it be determined whether or not a certain amino acid is essential for a particular kind of animal?
4. What is known about differences in the amino acid requirements for different body functions?
5. Why are the requirements of ruminants and horses for protein much more simple than in the case of pigs or chickens?
6. What is meant by protein of good quality?
7. Describe how the protein in one feed can supplement that in another.
8. What is the effect of excessive heating on protein quality; of long storage of feed?
9. What is meant by the time factor in protein supplementation?
10. How can a table showing the percentage of the essential amino acids help in making up efficient rations for pigs and poultry?
11. Describe one method of measuring the nutritive value of protein.
12. What quality of protein is furnished by the cereal grains; by wheat bran?
13. What is the quality of protein in milk, meat, fish, and eggs; in meat scrap, tankage, and fish meal?
14. Discuss the quality of protein in the following: (a) Well-cooked soybean oil meal; (b) raw soybeans; (c) peanut oil meal; (d) peas; (e) beans.
15. What is the quality of the protein in: (a) Linseed meal; (b) cottonseed meal; (c) coconut oil meal; (d) yeast; (e) dried distillers solubles?
16. Discuss the quality of protein in good forage crops.
17. What is known about the quality of the protein in good grass pasture?
18. What is the quality of protein in legume forage for ruminants?
19. Compare the importance of quality of protein for cattle or sheep with its importance for swine or poultry.
20. What pure amino acid is sometimes used in supplementing rations for poultry?
21. Under what conditions and for what kinds of stock may the use of urea as a protein substitute be economical?
22. What are the functions of fat in the body?
23. What is known about the needs of farm animals for a minimum amount of fat?
24. Why is by-product animal fat often added to formula feeds or to alfalfa meal?
25. Does the fat of milk have special value?
26. Discuss the value and functions of various carbohydrates.
27. What special value may molasses have in a ration?

REFERENCES

1. Robison, Ohio Buls. 617, 680; Carroll, Ill., mimeo. rpt.; Terrill, Warden, Becker, and Beamer, Ill., Jour. Amer. Vet. Med. Assoc., 121, 1952, pp. 304–305.
2. Forbes, Swift, Marcy, and Davenport, Penn., Jour. Nutr., 28, 1944, pp. 189–196.
3. Rose, Ill. Physiological Reviews, 18, 1938, pp. 109–136.

4. Loosli et al., N.Y., Science, 110, 1949, pp. 144–145; see also: Duncan, Huffman, and Agrawala, Mich., Jour. Dairy Sci., 35, 1952, p. 705; Reed, Moir, and Underwood, Australian Jour. Sci. Res., Series B, 2, 1949, pp. 304–317; McNaught et al., Biochem. Jour., 46, 1950, pp. 32–36.
5. Wooley, Jour. Biol. Chem., 159, 1945, pp. 753–754; see also: Swanson, Iowa Rpt. 1949; Maddy and Swift, Penn., Jour. Nutr., 47, 1952, pp. 243–262.
6. Elvehjem, Henderson, Maddy, and Wykes, Wis. Bul. 487.
7. Lewis and Elvehjem, Wis. Bul. 510; Cravens, Elvehjem, and Halpin, Wis., Poultry Sci., 29, 1950, p. 764.
8. McCollum, Wis., Jour. Biol. Chem., 19, 1914, p. 323; Hart and Steenbock, Wis., Jour. Biol. Chem., 38, 1919, p. 267; 43, 1924, p. 923.
9. Committee on Protein Foods, Nat. Res. Council, Reprint and Cir. Series 131, 1950.
10. Hathaway, Yung, and Kiesselbach, Nebr., Jour. Anim. Sci., 11, 1952, pp. 430–440; see also: Albert and Neumann, Ill., Jour. Anim. Sci., 14, 1955, p. 1192.
11. Mitchell and Beadles, Ill., Jour. Nutr., 39, 1949, p. 463–484; Ill. Rpt. 1938–47.
12. Cabell and Ellis, U.S.D.A., Jour. Anim. Sci., 14, 1954, pp. 1167–1173.
13. Geiger, Science, 111, 1950, pp. 594–599; Geiger, Bancroft, and Hagerty, Jour. Nutr., 42, 1950, pp. 577–585.
14. Eggert, Brinegar, and Anderson, Nebr., Jour. Nutr., 50, 1953, pp. 469–477.
15. Robertson, Carver, and Cook, Wash. Bul. 388; Carver and Wilhelm, Wash. Bul. 394; Evans and St. John, Jour. Nutr., 30, 1945, pp. 209–217.
16. Almquist, Stokstad, and Halbrook, Cal., Jour. Nutr., 10, 1935, pp. 193–211; Evans, St. John, and McGinnis, Wash. Bul. 470; Gehrt, Caldwell, and Elmslie, Jour. Agr. and Food Chem., 3, 1955, pp. 159–162.
17. Osborn and Mendel, Jour. Biol. Chem., 37, 1919, p. 557; Jones and Gersdorff, Jour. Biol. Chem., 64, 1925, pp. 241–251; Murphy and Jones, Jour. Biol. Chem., 69, 1926, pp. 85–99; Klein, Harrow, Pine and Funk, Amer. Jour. Physiol., 76, 1926, pp. 237–246.
18. Kik, Ark. Bul. 416; Maynard, Fonda, and Chen, N.Y., Jour. Biol. Chem., 55, 1923, pp. 145–155.
19. Carr, Spitzer, Caldwell, and Anderson, Ind., Jour. Biol. Chem., 28, 1917, pp. 501–509; Winter, Ohio Bul. 436.
20. Hughes and Hague, Ind., Jour. Nutr., 30, 1945, pp. 245–258.
21. Mitchell and Beadles, Ill., Jour. Nutr., 14, 1937, pp. 597–608.
22. Kik, Ark. Bul. 434.
23. Davis and Blaser, Fla. Rpt. 1946.
24. Crampton, Canada, Amer. Soc. Anim. Prod., Proc. 1934.
25. Sotola, Wash., Jour. Agr. Res., 40, 1930, pp. 79–96; Watkins, New Mex. Bul. 194.
26. Morrison and Turk, N.Y. (Cornell) Rpts. 1933, 1934; Turk, Morrison, and Maynard, N.Y., Jour. Agr. Res., 48, 1934, pp. 555–570; 51, 1935, pp. 401–412; Miller, Morrison, and Maynard, N.Y., Jour. Agr. Res., 54, 1937, pp. 437–448; Miller and Morrison, N.Y., Jour. Agr. Res., 58, 1939, pp. 149–155; Miller and Morrison, N.Y., Jour. Anim. Sci., 1, 1942, p. 353.
27. Swanson and Herman, Mo. Res. Bul. 372.
28. Lofgreen, Loosli, and Maynard, N.Y., Jour. Anim. Sci., 6, 1947, pp. 343–347; Hart and Humphrey, Wis., Jour. Biol. Chem., 21, 1915, p. 239; 26, 1916, p. 457; 31, 1917, p. 445; 35, 1918, p. 367.
29. For a review of the numerous investigations on urea as a protein substitute, see Reid, N.Y., Jour. Dairy Sci., 36, 1953, pp. 955–996; see also, Gallup, Pope, and Whitehair, Okla. Bul. B-409.
30. Hays et al., Iowa, Jour. Anim. Sci., 13, 1954, pp. 987–988; Hanson and Ferrin, Jour. Anim. Sci., 14, 1955, pp. 43–48; Slinger, Pepper, Hill, and Branion, Canada, Poultry Sci., 31, 1952, pp. 1106–1108.
31. Becker et al., Fla. Rpts. 1947, 1949, 1950; Ga. Rpt. 1946; Nevens, Harshbarger, and Kendall, Ill. Bul. 529; Archibald and Parsons, Mass. Bul. 425; Cullison, Miss., Jour. Anim. Sci., 3, 1944, pp. 59–62; Means, Miss. Farm Res., 7, 1944, No. 5; 8, 1945, No. 5; Klosterman, Bentley, and Moxon, Ohio, An. Sci. Mimeo. Ser., Nos. 79, 94; LaMaster, Mitchell, and Roderick, S.C. Rpt. 1945; Woodward and Shepherd, U.S.D.A., Jour. Dairy Sci., 27, 1944, pp. 648–649.
32. Davis, Wasserman, Loosli, and Grippin, N.Y., Jour. Dairy Sci., 38, 1955, pp. 678–687.
33. Hershberger, Engle, Bentley, and Moxon, Ohio, Jour. Anim. Sci., 14, 1955, pp. 1207–1208; see also: Tillman, Gallup, and McLaren, Okla., Jour. Anim. Sci., 14, 1955, p. 1224.
34. Hughes et al., Kan., Jour. Anim. Sci., 14, 1955, p. 1210; Parham, Frye, Kilpatrick, and Rusoff, La., Jour. Dairy Sci., 38, 1955, pp. 664–668; Pope et al., Okla. Misc. Pubs. MP-34, MP-43; Knodt, Williams, and Brumbaugh, Penn., Jour. Anim. Sci., 9, 1950, pp. 661–662; Magruder, Knodt, and Williams, Penn., Jour. Anim. Sci., 10, 1951, pp. 1055–1056; Tillman and Swift, Penn., Jour. Anim. Sci., 12, 1953, pp. 201–212; see also: King, O'Dell, LaMaster, and Roderick, S.C., Jour. Dairy Sci., 38, 1955, p. 624.
35. Richardson et al., Kan. Cir. 308; Rusoff, Landagora, Lee, and Bertrand, La., Jour. Anim. Sci., 13, 1954, p. 998; Barrentine and Darnell, Miss. Inform. Sheet 498; Tillman, Gallup, and McLaren, Okla., Jour. Anim. Sci., 14, 1955, p. 1224 and report at meeting of Amer. Soc. Anim. Prod., 1955.
36. Brown, Damon, Singletary, and Bertrand, La. Rpt. 1952; Tillman and Kidwell, La., Jour. Anim. Sci., 10, 1951, pp. 934–938; Magruder and Knodt, Penn., Jour. Dairy Sci., 36, 1953, pp. 581–582; Tillman and Swift, Penn., Jour. Anim. Sci., 12, 1953, pp. 201–212.
37. Kirk, Davis, and Peacock, Fla., Jour. Anim. Sci., 13, 1954, pp. 989–990.
38. Ferguson and O'Neave, Jour. Agr. Sci., England, 33, 1943, pp. 95–100.
39. Colo. Rpt. 1945.
40. Pope, Humphrey, Heller, and Campbell, Okla. Misc. Pub. MP-31.
41. Gaither, Garrigus, Forbes, and Hatfield, Ill., Jour. Anim. Sci., 14, 1955, p. 1203; Meiske, VanArsdell, Luecke, and Hoefer, Mich., Jour. Anim. Sci., 14, 1955, pp. 941–946.
42. Magruder and Knodt, Penn., Jour. Dairy Sci., 37, 1954, p. 657.
43. Paul and McCay, N.Y., Arch. Biochem., 1, 1942, pp. 247–253.
44. Cunningham and Loosli, N.Y., Jour. Dairy Sci., 37, 1954, pp. 453–461; see also: Lambert, Jacobson, Allen, and Zaletel, Iowa, Jour. Dairy Sci., 36, 1953, p. 591.
45. Siedler and Schweigert, Ill., Jour. Agr. and Food Chem., 2, 1954, pp. 193–195; Livingston, Bickoff, and Thompson, U.S.D.A., Jour. Agr. and Food Chem., 3, 1955, pp. 439–441.

CHAPTER VI

MINERALS IN LIVESTOCK FEEDING

138. Importance of minerals.—It has long been known that common salt, calcium, and phosphorus are necessary for the health of animals, and even for life itself. However, as late as thirty years ago, the knowledge was very limited concerning the exact amounts required of these minerals, and but little was known about the need for any other minerals.

Since that time, outstanding discoveries have been made concerning the mineral nutrition of animals. It has been found that in some areas or under certain conditions disastrous results are produced by a previously unknown lack of one of the trace minerals—iodine, copper, iron, cobalt, or manganese. The effects of a deficiency of calcium, phosphorus, or salt for the various kinds of farm animals have also been studied in detail, and the requirements for these minerals carefully determined.

These discoveries have caused much popular interest in the subject of minerals and have led to extensive use of mineral supplements in stock feeding. (For simplicity, the common practice is followed in this volume of referring to mineral nutrients or mineral compounds as "minerals.")

Although decided deficiencies of other minerals may occur that must be corrected by the use of a suitable mineral supplement, common salt is the only mineral that must generally be added to usual rations for cattle and sheep. To avoid expenditures for unnecessary mineral supplements, it is therefore important that stockmen know definitely the conditions under which there may be a lack of other minerals, and also know how to correct any deficiency at minimum cost. The use of mineral supplements when they are not needed is not only a waste of money, but also may in some cases be actually injurious.

One of the chief purposes of this chapter is to show when mineral supplements should be provided for stock, and when none is needed, except common salt. Further information about the mineral needs of each class of stock is given in Part III. The amounts of calcium and phosphorus in various feeds are shown in Appendix Table I, so far as data are available, and the amounts of other important minerals in typical feeds are given in Appendix Table IV.

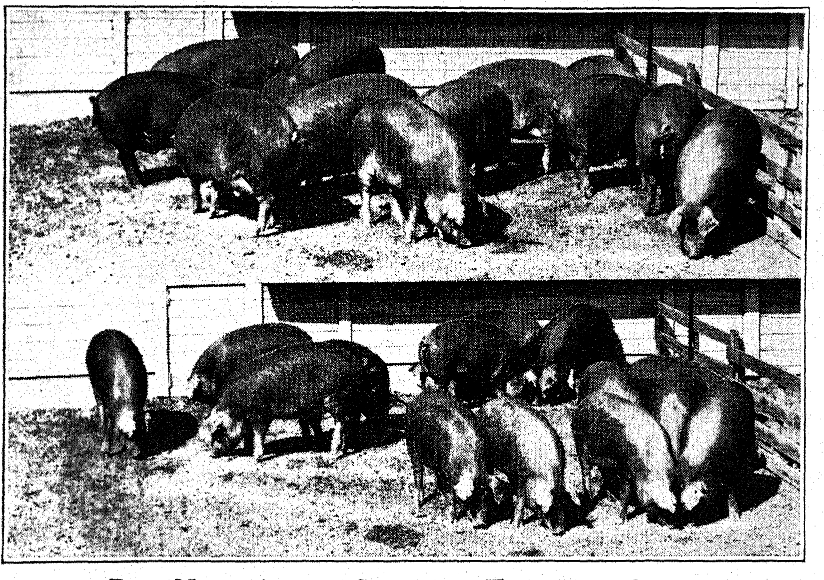
The amounts of calcium and phosphorus required by each class of the larger farm animals are stated in the Morrison feeding standards (Appendix Table III), and the mineral needs of poultry are shown in detail in Chapter XXXVI.

139. Functions of minerals.—Minerals have many vital functions in the body. First of all, the skeletons of vertebrate animals are composed chiefly of minerals (nearly all calcium and phosphorus). Minerals are also necessary constituents of the soft tissues and the fluids of the body. A few examples will serve to show how indispensable minerals are in the body. Phosphorus is a vital ingredient of the chief proteins in the nuclei, or life centers, of all body cells. It is also a part of certain other important proteins, such as the casein of milk. The phospholipids, which are phosphorus-containing fat-like substances, are essential parts of all living protoplasm. The power of the blood to carry oxygen is due to hemoglobin, the iron-protein compound in the red blood corpuscles.

The soluble mineral compounds in the blood and other body fluids are necessary to give these fluids their characteristic properties and to regulate the life processes. The acidity or alkalinity of the digestive juices is caused by mineral compounds. Thus, the acidity of the gastric juice in the stomach, which is neces-

sary for the action of the enzyme pepsin, is due to hydrochloric acid, formed from sodium chloride and other chlorides present in the blood. The osmotic pressure, needed for the transfer of nutrients and waste products through the cell walls, depends on mineral salts.

The maintenance of an approximately neutral reaction in body tissues, or the prevention of acidity or alkalinity, is due chiefly to a delicate adjustment of the mineral compounds in the body



PIGS NEED AMPLE SALT FOR EFFICIENT GAINS

Pigs supplied with salt in addition to a ration of corn plus soybean oil meal, alfalfa leaf meal, bone meal, and ground limestone, gained nearly twice as fast in Indiana experiments as those getting no salt. Upper lot: pigs supplied with salt. Lower lot: pigs getting no salt. (From Vestal, Indiana Station.)

fluids. A serious lack of calcium in the blood, such as occurs in milk fever of cows, causes convulsions and tetany.

For the various life processes, not only must there be sufficient supplies of the various essential minerals, but also there must not be a large excess of any of them. Thus, the regular beating of the heart depends on proper proportions of calcium and potassium in the blood. The kidneys are usually able to protect the animal against any excess of various minerals in the blood by excreting the excess in the urine. However, if the food continually furnishes an excessive amount of certain minerals, the body may be unable to keep the blood composition normal, and injury will result.

140. Sodium and chlorine; common salt.—Both sodium and chlorine are necessary for animal life, and farm animals usually do not secure enough of these two minerals in the feed they eat. To furnish these minerals, common salt (sodium chloride) should be supplied, except under unusual conditions.

Through recent investigations at certain experiment stations, partly financed by the Salt Producers Association, much new information has been gained concerning the requirements of farm animals for salt and for its two constituents, sodium and chlorine. These experiments have shown that at least in the case of dairy cows, sheep, and pigs, the chief deficiency in a ration made up of ordinary feeds, with no added salt, is sodium, rather than a lack of chlorine. The experiments dealing with the salt requirements of each kind of farm animals

are summarized in the respective chapters of Part III.

Cattle, sheep, horses, and other herbivorous animals (those that live chiefly on forage) need a somewhat greater proportion of salt in their rations than do swine or poultry, and show great hunger for salt when it is not supplied. Carnivora (flesh eating animals) secure sufficient salt in the flesh and blood they consume and therefore need no additional salt. If swine are fed meat scrap, tankage, or fish meal as the chief or only protein supplement, these feeds may supply enough salt. However, it is the safest plan to furnish them with salt even then.

The amount of salt needed may vary somewhat in different regions, depending on the salt content of the feeds grown there and on whether or not the water contains an appreciable amount of salt. Occasionally, in arid districts or very near the ocean where salt reaches the land from spray in the atmosphere, the forage, soil, or water may contain so much salt that there is no need of furnishing additional salt for livestock grazing there.

Salt may be provided in the form of loose salt, salt blocks, or lumps of rock salt, the choice depending on which form is cheapest or most convenient. An excellent method is to furnish a supply where the stock can take what they desire. They will not eat too much unless they have previously had an insufficient supply. They may then take so much at first as to cause indigestion, and therefore the amount should be limited at the start. For outdoor feeding in humid districts, placing the salt in suitable salt boxes will greatly reduce the wastage from weathering, especially if the boxes are protected from rain.

For dairy cows, 1 per cent of salt is generally included in the concentrate mixture, and then additional salt is provided so that they can take more if they wish. In the case of poultry, one-half per cent or less of salt is commonly included in the mash.

Salt stimulates the secretion of saliva and promotes the action of certain enzymes. It is an appetizer, as well as a nutrient, and animals may therefore consume more than they actually need. However, since salt is cheap, allowing them to take what they desire is wise.

Sodium and chlorine are important in maintaining the necessary osmotic pressure in the body cells, and sodium is the chief alkaline element concerned in maintaining neutrality in body tissues. Chlorine is required for forming the hydrochloric acid in the gastric juice. Blood is much richer in sodium and chlorine than in other minerals.

Sodium and chlorine are normally excreted chiefly in the urine. Also, sweat is high in these minerals. When the salt intake is large, the excess must be excreted in the urine, and about 5 gallons of urine must be produced for each pound of salt consumed.

When men do hard work at unusually high temperatures and sweat profusely, as in deep mines and furnace rooms, they suffer less from fatigue if they take salt tablets regularly or drink water containing a small amount of salt. This replaces the salt lost in the sweat. Similarly, it is important to provide plenty of salt for horses doing hard work in hot weather.

If animals receive insufficient salt, the body retains its supply tenaciously, and the excretion in the urine is greatly reduced. However, if the lack is severe and long continued, injury results. The digestibility of food is lessened, appetite is much decreased, growth declines, and reproduction may be impaired.

141. Consuming large amounts of salt.—Farm animals are not harmed by consuming considerably larger amounts of salt than they need. Advantage is taken of this fact in mixing salt with a protein supplement for cattle or sheep on the range, and then self-feeding the mixture to save labor, instead of hand-feeding the protein supplement each day. The percentage of salt in the mixture is regulated so that the stock will eat the needed amount of protein supplement, and no more. The experiments in which this method has been tested are summarized in Chapters XXVIII and XXX.

Surprisingly large amounts of salt

may be consumed without injury in this method. For example, beef cows have eaten over 2 lbs. of salt daily in such a mixture for long periods with no harm. In this method it is essential that the animals have access to plenty of water, conveniently available, so that they can get rid of the excess salt through the urine.

Salt poisoning of stock may occur, if animals have access to brine or unusually salty whey, when water is not readily available. A very large percentage of salt in the mash may kill poultry. For example, chicks were killed in one experiment when 5 per cent of salt was included in the ration.[1] On the other hand, in another test chickens grew normally on a ration having as much as 8 per cent salt.[2]

142. Calcium and phosphorus.—Farm animals are more apt to suffer from a lack of phosphorus or of calcium than of any of the other minerals except common salt. Calcium and phosphorus compounds make up about three-fourths of the mineral matter in the entire bodies of farm animals and over 90 per cent of that in their skeletons. Compounds of these minerals also form more than half the minerals in milk. Therefore liberal amounts of calcium and phosphorus are needed by growing animals, by those that are pregnant, and by those which are producing milk. Even for merely maintaining mature animals, sufficient amounts of these minerals must be provided to replace the daily losses from the body, or injury will finally result.

In order to assimilate and use the calcium and phosphorus in their food efficiently, animals must have sufficient vitamin D. As is shown in the next chapter, this may be furnished either in the feeds they eat or through the effect of sunlight or other light that contains ultraviolet rays. Also, the ratio, or proportion, between the amount of calcium and the amount of phosphorus in the ration should be within certain limits. A great excess of one of these minerals may be detrimental, even though the supply of the other is ample. The importance of this factor is discussed later.

There is now more apt to be a need of a calcium or phosphorus supplement in addition to usual rations than in early days. This is because of two factors. First, the supply of these minerals in the common feeds, especially in roughages, has decreased in the older farming districts, because the calcium and phosphorus content of the soil has been depleted. Second, the requirements of farm animals for these minerals have become much greater, as their rates of production of meat or milk have been increased through breeding and through improved and more intensive methods of feeding and management.

Under many conditions there is a plentiful supply of both these minerals in the rations for farm animals, without the addition of any special calcium or phosphorus supplements. On the other hand, a lack of one or both of these minerals may sometimes occur which lowers production or even causes serious injury. It is therefore highly important to know whether or not there are sufficient amounts of these minerals in any particular ration.

The requirements of the farm animals, except poultry, for calcium and phosphorus are stated in the Morrison feeding standards, and the requirements of poultry are shown in Chapter XXXVI. Specific information is also given in Part III as to whether or not various common rations are lacking in calcium or phosphorus, and recommendations are there made for the correction of any such deficiencies.

Stock require somewhat more calcium than phosphorus, because the amount of calcium in their bodies is much greater than of phosphorus. Also, milk contains slightly more calcium than phosphorus. In spite of these facts, there is less apt to be a lack of calcium than of phosphorus in the rations of cattle, sheep, or horses. This is because roughages generally make up a large part of the feed eaten by these animals, and most roughages contain much more calcium than phosphorus. Only when such animals are fed largely on grain and other concentrates or when the rough-

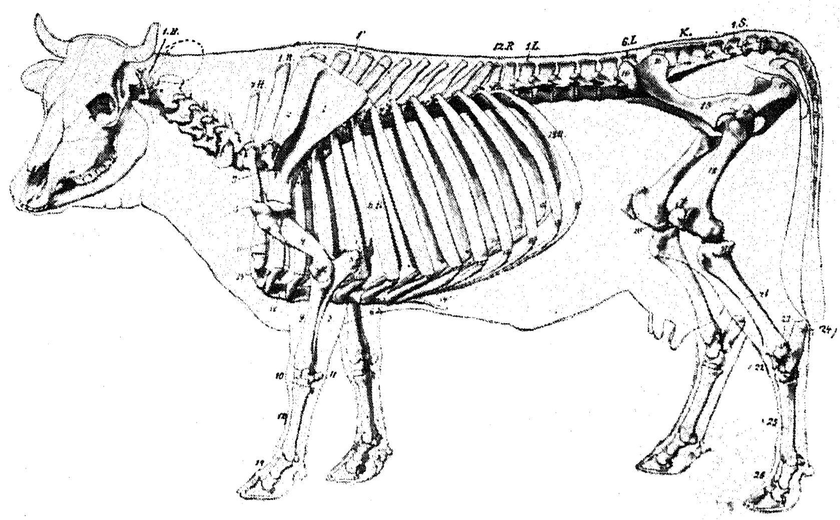
age is unusually poor, is there apt to be a lack of calcium.

The condition is, however, far different in the case of swine and poultry. They are commonly fed chiefly on grain and grain by-products, all of which are very low in calcium, but are fair or even high in phosphorus.

Also, poultry require much higher percentages of calcium and phosphorus in their rations than do other classes of stock, and the need for calcium for egg shell formation is particularly great. Both calcium and phosphorus supplements must therefore be added to most poultry rations.

Swine need somewhat greater percentages of calcium and phosphorus than do cattle or sheep. They generally need a calcium supplement, unless calcium-rich protein supplements, such as meat scrap, tankage, fish meal, or milk, are fed in sufficient amounts. Also, it is beneficial to add a phosphorus supplement to some common swine rations.

Young animals have much greater ability to absorb and use calcium than do older ones. It is shown later that in the case of very old animals, it may be difficult to prevent a loss of calcium from the body, even when they are fed a ration that would supply plenty for younger ones. (245) It is therefore important that aged animals have abundant calcium.



GROWING ANIMALS NEED ABUNDANT CALCIUM AND PHOSPHORUS

Over 90 per cent of the mineral matter in the skeleton consists of calcium and phosphorus. In certain rations the amounts of these minerals may be insufficient for health. (From Ellenberger.)

143. Composition and formation of bone.—The bones of mature animals contain about 26 per cent of mineral matter, 20 per cent of protein, 4 per cent of fat, and 50 per cent of water. Approximately 85 per cent of the mineral matter is calcium phosphate, 14 per cent calcium carbonate, and 1 per cent magnesium phosphate or carbonate.

The growth of bones in length occurs in a zone near the ends of the long bones. Here the mineral compounds are deposited in a temporary zone of cartilage. Bone increases in diameter by formation of bone under the periosteum, the membrane which covers the bones.

The chief strength of a long bone is due to the dense, compact bone in the outer shaft. Inside the bone, especially near the ends, is spongy bone, made up of a lace-like bony network (called "trabeculae"). This spongy bone serves as a reserve store of calcium and phos-

phorus that can readily be drawn upon when the supply in the feed is insufficient to meet the needs. When the supply is more liberal or the needs are less, the store can then be replenished. It is shown in Chapter XXV that a high-producing cow normally draws on this store of minerals in her skeleton at the height of milk production. (1037)

Unless the draft on the calcium and phosphorus lasts too long, the animal is not injured at all by this process. However, if the shortage continues unduly long, the supply in the spongy bone will be exhausted, and calcium and phosphorus will be drawn from the shafts and other supporting parts of the bones. This will weaken them and may produce serious injury.

144. Calcium and phosphorus content of feeds.—Because of the importance of calcium and phosphorus, the author has compiled the available data concerning the amounts of these minerals in various feeds. These averages are given in Appendix Table I. It will be noted that such information is still limited, in comparison with the data for the content of protein, fat, fiber, nitrogen-free extract and total mineral matter in feeds.

In using these figures it must be remembered that the amounts of these minerals in any particular lot of feed, especially of a roughage, may differ considerably from the average. When grown on soil low in available phosphorus or in calcium, roughages will generally contain decidedly less of the mineral than when grown on fertile soil. At early stages of growth, forage plants contain much more calcium and phosphorus, on the dry basis, than at later stages.

145. Calcium content of roughages.—One of the most important facts concerning the calcium content of feeds is that legume hays and all other legume forages except legume straw are very rich in calcium. Alfalfa hay of average quality has 1.47 per cent calcium; red clover hay, 1.28 per cent; and soybean hay, 1.10 per cent. Though the calcium content of legume forage is influenced to some extent by the amount of this mineral in the soil, one can always safely count on its being relatively rich in calcium. If the soil is too deficient in calcium, legume crops will not grow.

Non-legume roughage in general contains much less calcium than that from legumes, and if grown on soil deficient in calcium, such roughage may be considerably lower in this mineral than indicated by the average figures. Timothy hay of average quality has 0.35 per cent calcium; good-quality hay from mixed grasses, 0.48 per cent; and dry corn stover, 0.54 per cent.

Grass that is mature, and especially that which is weathered, is lower in calcium than immature grass. However, there is generally less difference in the calcium content than in the content of phosphorus. Even mature, weathered grass generally has a fair content of calcium, while the phosphorus may be seriously low.

Cereal straw is slightly lower than grass hay in calcium content. Silage from corn or the sorghums contains about as much calcium, on the dry basis, as does hay from the grasses. Roots and tubers are generally low in calcium.

146. Calcium content of concentrates.—All of the cereal grains are exceedingly low in calcium, the content ranging from only 0.02 per cent in corn to 0.09 per cent in oats. None of the by-products of the grains is rich in calcium, and wheat bran, wheat middlings, corn gluten meal, and corn distillers dried grains are all low. Most oil meals are low to fair in calcium, peanut oil meal having 0.16 per cent, soybean oil meal 0.27 per cent, and linseed meal 0.37 per cent.

In the process of manufacture lime is added to certain by-products, thus increasing the calcium content. For this reason dried citrus pulp has 1.98 per cent calcium, dried beet pulp 0.69 per cent, and corn gluten feed 0.41 per cent.

Milk and the animal by-products that contain bone, such as meat scrap, tankage, and fish meal, are rich in calcium. On the dry basis milk has about as much calcium as does legume hay,

dried skimmilk having 1.28 per cent. Fish meal has 5.36 per cent calcium, and meat scrap of the 50-per-cent-protein grade contains so much bone that it has 10.67 per cent calcium.

147. Phosphorus content of roughages.—There are striking differences in the content of phosphorus and of calcium in various feeds. While legume forage is rich in calcium, none of the roughages is rich in phosphorus. The phosphorus content of various hays usually ranges from 0.15 per cent or even less, up to 0.30 per cent. Legume hay contains but little more phosphorus than grass hay of similar quality.

Early in their growth, grasses and legumes have a much larger percentage of phosphorus on the dry basis than at the hay stage. Thus, mixed pasture grasses and clovers from well-grazed, fertile pastures have 0.58 per cent phosphorus on the air-dry basis. Fodder and silage from corn or the sorghums generally have slightly less phosphorus, on the dry basis, than grass hay. The stover from these crops, the straws from the small grains, and likewise such feeds as cottonseed hulls and flax straw are very low in phosphorus. On the dry basis some roots and tubers are slightly higher in phosphorus than the hay crops, while sweet potatoes are low.

A decided phosphorus deficiency of the soil reduces the phosphorus content of forage even more than a lack of calcium lowers the calcium content. Pasturage, hay, or other forage from land poor in phosphorus may be so low in the mineral that it produces serious phosphorus deficiency in stock, if it is the only source of phosphorus.

Also, the phosphorus content of the grasses is greatly lowered as the plants mature and especially as the dried plants become weathered. Mature, weathered range forage is therefore often very low in phosphorus.

148. Phosphorus content of concentrates.—The cereal grains contain a fair amount of phosphorus, differing decidedly in this respect from their very low content of calcium. The percentage of phosphorus ranges from about 0.27 per cent in corn grain to 0.39 per cent in wheat.

A very important fact is that most of the protein-rich by-product concentrates of plant origin are much higher in phosphorus than are the grains or the roughages. Wheat bran is especially rich in phosphorus, containing 1.29 per cent. Standard wheat middlings have 0.93 per cent; cottonseed meal of the usual grades, 0.89 to 1.19 per cent; and linseed meal, 0.86 per cent. Wheat flour middlings have less phosphorus than standard middlings, and wheat red dog flour contains still less.

The protein-rich legume seeds are medium in phosphorus, soybeans having 0.59 per cent; field peas, 0.50 per cent; and cowpeas, 0.46 per cent. Soybean oil meal contains 0.63 per cent phosphorus and peanut oil meal 0.54 per cent. Corn gluten meal is relatively low in phosphorus for a protein-rich concentrate, while corn gluten feed has an average of 0.80 per cent.

Milk is nearly as rich in phosphorus as it is in calcium, dried skimmilk having 1.04 per cent phosphorus, for example. Because of the bone they contain, meat scrap, tankage, and fish meal are very high in phosphorus as well as being rich in calcium. Thus, meat-and-bone scrap of the 50-per-cent-protein grade contains 5.27 per cent phosphorus, and fish meal 3.42 per cent. On the other hand, dried blood is relatively low in both phosphorus and calcium, having 0.25 per cent phosphorus and 0.32 per cent calcium.

149. When do lacks of calcium occur?—Certain general conclusions can be drawn from these data on the calcium and phosphorus content of various classes of feeds. It is shown in Part III that dairy cattle, beef cattle, sheep, and horses do not need more than 0.2 to 0.3 per cent of calcium in their rations on the air-dry basis, except in the case of very young animals.

Legume forage, no matter whether it is hay, silage, or pasturage, usually has about 1.0 per cent or more of calcium on the air-dry basis. Therefore when legume forage forms any important part

of the ration for cattle, sheep, or horses, there will ordinarily be an abundance of calcium. Even when no legume roughage is fed to these classes of stock, there will usually be no deficiency of calcium unless the roughage is grown on soil very low in calcium or unless they are fed largely on grain and other concentrates, with only a limited amount of roughage.

Although good dairy cows need large amounts of calcium for the milk they produce, it is shown in Chapter XXV that generally there is not apt to be a deficiency of calcium in their rations when they are fed good roughage, even if none of it is legume forage. (**1036**) However, when no legume roughage whatsoever is fed to dairy cows, it is probably wise to furnish additional calcium as insurance against any possible lack, unless the non-legume roughage comes from soil well supplied with calcium.

It is shown in Chapters XXVIII and XXX that when young cattle or lambs are fattened on liberal amounts of grain, with non-legume roughage and such protein supplements as soybean oil meal or linseed meal, there may be a decided lack of calcium in the ration. This is because they do not eat enough roughage to meet their calcium requirements. In such cases there will generally be a great benefit in rate and economy of gain from feeding a calcium supplement, such as ground limestone.

If the animals have been raised previous to the fattening period in an area where the forage is high in calcium, they may have in their bodies a sufficient store of the mineral to meet their needs during the usual fattening period. They may then show little or no benefit from the addition of a calcium supplement.

There is an entirely different situation with reference to the need for additional calcium in the rations of swine and poultry. For the reasons stated previously in this chapter, a calcium supplement is needed in most poultry rations, and swine also generally need additional calcium. (**142**)

Disastrous results may be caused by stock eating too much of certain plants that contain considerable oxalic acid or soluble salts of oxalic acid. On being absorbed by an animal, these react with the calcium in the body to form insoluble calcium oxalate, and the animal may die from the resulting extreme calcium deficiency. This is the cause of the severe losses from halogeton poisoning on certain western range areas. (**675**)

150. When are there deficiencies of phosphorus?—Since the cereal grains are fair in phosphorus content and most protein-rich concentrates are rich in this mineral, there will generally be no lack of phosphorus when stock are fed a considerable proportion of these feeds in a well-balanced ration. However, when the ration is balanced only by protein supplements not rich in phosphorus, there may be a lack.

The phosphorus supply for beef cattle, sheep, and horses will be ample even when they are fed entirely on roughage, if the forage has been grown on soil reasonably well supplied with the mineral. On the other hand, there may be a serious deficiency of phosphorus if stock are fed chiefly on phosphorus-poor forage, without any supplement that is high in this essential.

There are large areas in this and other countries where the forage is so deficient in phosphorus that serious results are produced in livestock unless this lack is corrected. In these areas the soil is so lacking in available phosphorus that the forage grown on it is very low in the mineral. As has been pointed out in Chapter IV, the percentage of phosphorus in grain and other seeds is affected much less by a deficiency of phosphorus in the soil, but the yield may be reduced severely. (**99**)

Fertilization with superphosphate or other phosphorus fertilizers not only greatly increases the yields of crops in such areas, but also generally produces feeds of normal phosphorus content and therefore prevents injury to stock from a lack of the mineral. Wherever fertilization of the land is not practicable, as on range areas, trouble from phosphorus deficiency may be prevented by supplying

bone meal or some other safe phosphorus supplement.

Because of the higher phosphorus requirements of dairy cows, a ration of roughage alone or even of roughage and farm grain is apt to be deficient in phosphorus. (**1035**) Therefore, unless one is sure that the hay or other roughage has a good content of phosphorus, a phosphorus supplement should be added to such rations.

When meat scrap, tankage, or fish meal are used as the only or the chief protein supplements in rations for swine or poultry, there will generally be no need of adding a phosphorus supplement. On the other hand, a phosphorus supplement should be used when the ration is balanced largely with such a protein supplement as soybean oil meal, which is not very high in phosphorus.

151. Value of phosphorus in various feeds.—In some cases it is necessary to consider not only the amounts of phosphorus in various feeds, but also the form in which the phosphorus is present. A large part of the phosphorus in seeds and their by-products is in the form of phytin, an organic phosphorus compound. Investigations have shown that the phosphorus of phytin is not so well assimilated by certain animals as phosphorus in other forms. This is especially the case with poultry. As shown in Chapter XXXVI, in poultry rations a certain proportion of the phosphorus must therefore be supplied in non-phytin form, such as bone meal or other suitable phosphorus supplements. Hens can use phytin phosphorus somewhat better than can chicks. Recent experiments mentioned in Chapter XXXIV indicate that pigs utilize phytin phosphorus less efficiently than non-phytin phosphorus.

The assimilation of phytin phosphorus is improved when the ration has a plentiful amount of vitamin D. It may also be increased when the ration contains natural, unheated roughages, for these contain an enzyme which splits off the phosphorus from the phytin.

Experiments have shown that ruminants can use phytin phosphorus satisfactorily. The phosphorus in roughages is generally well utilized by stock.

152. Calcium-phosphorus ratio.—It has been mentioned previously that not only must animals receive adequate amounts of calcium and phosphorus, but also there should be a suitable proportion, or ratio, between the amounts of these two minerals. If there is a great excess of calcium or of phosphorus, detrimental effects may be produced, even when there is an amount of the other mineral that would be adequate under usual conditions. Also, less vitamin D is needed in the ration when there is a desirable calcium-phosphorus ratio.

Apparently, little attention need be given to the ratio between the amounts of calcium and phosphorus in feeding cattle or sheep, if there is a plentiful supply of each mineral. However, recent experiments with beef calves have shown that when there is a slight shortage of phosphorus in the ration, adding a calcium supplement that is not needed may increase the phosphorus deficiency.[3]

With an ample amount of both calcium and phosphorus, the results have been satisfactory when cattle have been fed rations having calcium-phosphorus ratios ranging all the way from more than 6 to 1 down to 0.6 to 1.[4] (A ratio of 6 parts of calcium to 1 of phosphorus is written as a ratio of 6 : 1.) In a recent New Hampshire investigation, however, adding an excessive amount of ground limestone (0.2 lb. per head daily) to a ration for dairy heifers slightly decreased the digestibility.[5] Adding half as much limestone did not have this undesirable effect.

For swine, rations having calcium-phosphorus ratios between 1.1 : 1 and 1.5 : 1 seem to be most satisfactory,[6] and for chicks a calcium-phosphorus ratio of about 1.5 : 1.[7]

153. Effects of phosphorus or calcium deficiency; rickets.—A decided deficiency of phosphorus or calcium, or a failure to utilize these minerals because of a lack of vitamin D, will cause rickets in growing animals and will also produce serious trouble in mature animals.

Even a moderate lack may result in a weak skeleton that cannot withstand the usual strains and shocks.

The term *rickets* is commonly used for the disease produced in young animals by a lack of calcium, phosphorus, or vitamin D. (Sometimes the term is used also for similar diseases in mature animals.)

In rickets the blood becomes deficient in phosphorus or calcium or in both of these minerals. As a result, normal amounts of phosphorus and calcium are not deposited in the growing bones. The bones are therefore weak and are readily broken or fractured. In an attempt to overcome the weakness, the long bones become abnormally large at the ends, where the growth takes place. Thus, characteristic enlargement, or "beading," often results at the ends of the ribs. If rickets develops at an early age, the legs may become decidedly deformed.

Among the larger farm animals, rickets occurs most frequently in young dairy cattle and in pigs. The methods of preventing this trouble in these animals are therefore discussed fully in Chapters XXVII and XXXIV.

In young cattle characteristic symptoms of rickets are stiffness, swollen joints, bent knees, and an arching of the back, except immediately at the rear of the shoulders, where there is often a sag. The animal frequently stands humped up with middle drawn up and is often easily excited and may have attacks of fits. Respiration is rapid, and the animal becomes exhausted from slight exertion. A depraved appetite may develop, as shown by the chewing of bones, wood, or hair. In severe cases the animal may show a decided lack of appetite, especially for roughage.

The most marked symptom of rickets in pigs is stiffness of the legs. This is usually accompanied by a general unthrifty appearance and failure to make good gains in weight. Eventually, paralysis of the hind legs often occurs. This is due, at least in certain cases, to a fracture of one of the vertebrae and the resulting crushing or constriction of the spinal cord.

If the disease has not advanced too far, the animal will usually recover when supplements are added to the ration that furnish liberal amounts of vitamin D, calcium, and phosphorus. However, recovery may be slow if it has reached the stage where there is a marked lack of appetite. Also, it may be impossible to overcome malformations of the skeleton produced by the disease.

CALVES SUFFERING FROM RICKETS

The calf on the left has a mild case of rickets. It is beginning to show the characteristic arching of the back, swollen knees, and stiffness. Note the tendency to develop long toes. The calf on the right has a very bad case of rickets. Note the crippled condition, bent and swollen knees, swollen hocks, and badly arched back. (From Huffman, Michigan Station.)

154. Phosphorus or calcium deficiency in mature animals.—In the case of mature animals a deficiency of phosphorus or calcium or a lack of vitamin D produces mineral-deficiency diseases that are somewhat different from rickets.

Phosphorus and calcium are with-

drawn from the bones to meet the needs for these minerals by the body. The store of these minerals in the spongy part of the bone will be drawn on first. If the deficiency is not too serious or continued too long, the strength of the skeleton will not be injured. However, if the withdrawal continues, phosphorus and calcium will be taken from the shafts and other structural parts of the bones. As a result, the bones become porous and weak, and are easily broken. The animals also often become lame or stiff, because of injury to the joints.

The term *osteomalacia* is most frequently used for the deficiency diseases in mature animals caused by a lack of phosphorus or calcium or a deficiency of vitamin D. Other names given to these troubles are pica, stiffs, and osteoporosis. Sometimes these diseases are included under the term rickets, but this term is best used only for the similar disease in growing animals.

If breeding females are fed rations seriously deficient in phosphorus or calcium, the body of the mother does its utmost to protect the young against the lack by withdrawing the mineral from her skeleton. In extreme cases, normal reproduction may be prevented and the young may be born weak or even dead. This is much more apt to occur in the case of brood sows than with herbivora, for sows fed on only grain and grain by-products receive a ration that is disastrously deficient in calcium.

155. Effects of phosphorus deficiency.—One of the first symptoms of a deficiency of phosphorus is a lack of appetite and a run-down, unthrifty appearance.[8] Animals that are still growing will fail to make normal gains, and those producing milk will drop off greatly in yield. A continued lack of phosphorus will generally cause a depraved appetite, and the animals will gnaw bones, wood, or other objects, or eat dirt in an instinctive effort to secure the needed mineral. In severe cases of phosphorus deficiency the animals sometimes no longer show a depraved appetite, but are listless and have little desire for food.

Heavy death losses of cattle from botulism have occurred on phosphorus-deficient range pasture, due to the eating of decayed bones or flesh in which the botulinus toxin has been produced.

A long-continued phosphorus deficiency will often cause stiffness of the joints, and the bones may also become fragile and easily broken. A severe lack of phosphorus in breeding females may cause weak or dead offspring. The milk yield may also be so low that the mother is unable to nurse her young properly. High-producing cows and young stock are usually affected most by the deficiency, because of their greater needs for the mineral. In phosphorus-deficient areas cows frequently fail to come in heat regularly and often do not calve more than once in two years.

In cases of phosphorus deficiency, animals not only have poor appetites and eat less feed than normal, but also they utilize poorly that which they do consume.[9] In phosphorus deficiency, the digestibility of the feed is not appreciably reduced, but the digested nutrients are utilized inefficiently. In cattle, but not in sheep, the conversion of carotene into vitamin A in the body may apparently be interfered with.

156. Effects of calcium deficiency.—It has been shown previously in this chapter that cattle, sheep, or horses are not apt to lack calcium when good roughage forms a large part of their rations. (149) However, in a few areas the soil is so deficient in calcium that serious trouble occurs unless a calcium supplement is provided. (1036) Injury from calcium lack may also result if dairy cows are fed only a small quantity of poor-quality grass hay with a concentrate mixture having no added calcium supplement.

While dairy cows suffering from phosphorus deficiency are commonly thin and run-down in condition, those affected by a lack of calcium may be in good flesh if fed liberally on concentrates. However, their milk yield may be greatly reduced, and their bones may break without any unusual strain or shock.

Because of the deficiency of calcium in all the grains, care is necessary to make sure that swine and poultry are provided with plenty of this mineral. It is shown in Chapter XXXIV that a lack of calcium in the rations of brood sows may cause reproductive failure. The serious effects of a deficiency of calcium upon hens are discussed in Chapter XXXVI.

157. Calcium supplements.—When a ration is fed that is deficient in calcium, in phosphorus, or in both of these minerals, the lack should be corrected by the use of a suitable mineral supplement. In deciding what supplement to use, one should first determine which mineral is lacking. If the ration is deficient only in calcium and has plenty of phosphorus, it is uneconomical to use a supplement like bone meal, which furnishes both of these minerals. Such supplements cost much more than ground limestone or other calcium supplements. Also, if there is already plenty of phosphorus in the ration, it may be detrimental to add considerably more.

Ground limestone, which is mostly calcium carbonate, is the most commonly-used calcium supplement. This is generally cheap and is readily available in most areas. *High-calcium limestone*, or calcitic limestone, is to be preferred as a calcium supplement, for the value depends on the actual amount of calcium present. Such limestone has about 38.5 per cent of calcium. Sometimes "mineralized limestones," to which small amounts of such minerals as manganese or iodine have been added, are sold at prices that are extremely high, in comparison with ordinary limestone, considering the actual amounts of added minerals.

Dolomitic limestone, which contains considerable magnesium carbonate, is a fairly satisfactory calcium supplement, except for poultry. In Ohio tests the use of dolomitic limestone in place of high-calcium limestone lowered the egg production and tended to produce eggs with weak or thin shells.[10] For other stock dolomitic limestone has been equal in some experiments to high-calcium limestone, when fed at an equal calcium level, but in other tests it has not produced as good results.[11]

Ground oyster shell is an excellent calcium supplement and is very popular for poultry.[12] It contains approximately as much calcium as high-calcium limestone. Ground clam shell,[13] mussel shell,[14] coquina shell,[15] and coral[16] are also satisfactory calcium supplements.

Marl is satisfactory as a calcium supplement when it does not contain too large a proportion of clay or sand. Its value per ton will obviously depend on the amount of calcium it supplies.

Precipitated calcium carbonate, a by-product from soap and sugar factories, is sometimes available for use as a mineral supplement and is entirely satisfactory for the purpose.

Wood ashes contain about two-thirds as much calcium as does ground limestone and may be used in place of it as a calcium supplement, when available on the farm.

Gypsum supplies calcium in the form of calcium sulfate instead of calcium carbonate, as in limestone and the other calcium supplements that have been mentioned. It is apparently satisfactory for use as a calcium supplement in stock feeding, except for laying poultry.[17] To meet the heavy demand for calcium in egg-shell formation, calcium in carbonate form, as in limestone or in oyster shell, is much superior to that in gypsum or in bone meal or other phosphate sources.[18]

Basic slag was a satisfactory calcium supplement for pigs in Mississippi tests.[19]

Unslaked lime or *water-slaked lime* (hydrated lime) should not be fed to stock, because of the caustic nature of these forms of lime.

158. Phosphorus supplements.—In using a phosphorus supplement for livestock feeding, it is necessary to see that the product does not have a dangerous amount of fluorine. As is explained later, if rations contain more than certain very small amounts of fluorine, livestock are injured. (168–169)

Bone meal and products made from

bone are entirely safe, as they have only a very small amount of fluorine. On the other hand, phosphates of rock origin generally contain dangerous amounts of fluorine unless they have been thoroughly defluorinated, or specially treated at a high temperature to remove most of the fluorine.

The common phosphorus supplements supply calcium as well as phosphorus, bone meals and spent bone black having about twice as much calcium as phosphorus.

Information is given in Part III on the relative values of the different phosphorus supplements for the various classes of stock, so far as data are available.

159. Steamed bone meal.—Steamed bone meal, often called merely "bone meal," is the most common phosphorus supplement for stock feeding. It contains an average of 30.14 per cent calcium and 14.53 per cent phosphorus, with 7.5 per cent protein and 1.2 per cent fat. If solvent-extracted, the average fat content is only 0.4 per cent.

In the production of steamed bone meal for feeding purposes, fresh bones of suitable quality are cooked under steam pressure very thoroughly. This extracts most of the protein and fat, which are used for other purposes. The residue is pressed and dried, and then ground.

Raw material of much better quality should be used in making bone meal for stock feeding than for fertilizer bone meal. For feeding, only bone meal should be bought that has definitely been made for this purpose and that has been so prepared that it is entirely free from any disease-producing organisms. Fertilizer bone meal often has a rank, disagreeable smell, differing decidedly from good-quality steamed bone meal.

Special steamed bone meal is similar to ordinary bone meal, except that it is produced in the manufacture of gelatin and glue from selected bone. It commonly has a trifle more calcium and phosphorus and a little less protein than does steamed bone meal. It has very little odor and is nearly white.

160. Cooked bone meal.—This by-product, formerly called raw bone meal, is not uncooked, but is thoroughly cooked in open kettles, instead of under steam pressure, as in the making of steamed bone meal. Because of the lower temperature, the protein is removed less completely, and cooked bone meal is therefore lower in phosphorus and calcium. It has an average of 26.0 per cent protein, 5.0 per cent fat, 22.96 per cent calcium and 10.25 per cent phosphorus. Cooked bone meal is sometimes ground more coarsely than steamed bone meal and screened into various sizes for poultry of different ages.

161. Spent bone black, or bone char.—Bone black is a granular product made by charring bone in closed retorts and grinding it coarsely. It is employed especially for clarifying and decolorizing the sirup in the manufacture of cane or beet sugar and in making table sirups. After the bone black has once been used and has taken up organic impurities, it is re-charred and used again. Finally, it becomes too powdery for further use, and is then dried and sold as *spent bone black*, or bone char, for stock feeding or for fertilizer.

Though black in color, spent bone black may have nearly as much phosphorus and calcium as steamed bone meal. It may be used in the same manner as steamed bone meal in stock feeding.

162. Rock phosphate; phosphorized limestone.—Most *rock phosphate* (sometimes called "lime phosphate") contains 3.25 to 4 per cent of fluorine. Experiments have proved that this high flourine content makes it unsafe for feeding to livestock as a phosphorus supplement for any long period, except possibly as part of the phosphorus supplements for poultry.

The rock phosphate from a few areas, especially the West Indian island of Curacao, generally has a much lower amount of fluorine. In using such phosphate for feeding, one should be sure that the level of fluorine is safe.

Phosphorized limestone is also unsafe for continued feeding to livestock.

It is part way between limestone and rock phosphate in chemical composition. Though the percentage of fluorine is lower than in rock phosphate, the proportion between the amounts of phosphorus and of fluorine is nearly the same as in rock phosphate. Therefore, if enough phosphorized limestone is fed to supply a certain amount of phosphorus, the ration will have nearly as much fluorine as though rock phosphate had been used.

In an instance which came under the observation of the author, disastrous results were produced in a dairy herd which, according to the owner, had been fed phosphorized limestone as a mineral supplement for 3 to 4 years. This had been done in a mistaken and vain effort to eradicate brucellosis, or Bang's disease, by the use of a mineral supplement.

163. Soft phosphate with colloidal clay, or colloidal phosphate.—This product is nothing but a mixture of fine particles of rock phosphate and clay. It is the fine material that is washed out of pebble rock phosphate in preparing the rock for crushing. Formerly the material was wasted, but it now is sold as a phosphate fertilizer and sometimes as a mineral supplement for livestock. It has about 18 per cent calcium and only 9 per cent phosphorus. In proportion to the content of phosphorus, it has nearly as much fluorine as does rock phosphate, and is therefore not safe for continued feeding.

In certain experiments with chicks and pigs, summarized in Part III, soft phosphate with colloidal clay has not been a satisfactory phosphorus supplement.

164. Superphosphate.—In the manufacture for fertilizer of superphosphate from rock phosphate, most of the fluorine is not removed. Therefore, superphosphate should not be used for feeding to livestock over any long period. For example, in a New York test with chicks superphosphate produced satisfactory results for 2 months, but by the end of 10 months over half of the chickens fed superphosphate had died.[20] Those that lived had grown much slower than others fed bone meal.

165. Defluorinated phosphates.—During the serious shortage of steamed bone meal in World War II, methods were developed for removing nearly all the fluorine from rock phosphate to produce defluorinated phosphate. According to the definition of the Association of American Feed Control Officials, defluorinated phosphate must not contain more than 1 part of fluorine to each 100 parts of phosphorus.[21] Such defluorinated phosphate is an entirely safe substitute for bone meal. It may be somewhat less palatable than bone meal.

The availability of the phosphorus and calcium in the defluorinated phosphates now made in this country is nearly equal to that in bone meal, while the phosphorus in certain of the products made earlier was much less available.[22]

166. Dicalcium phosphate; monocalcium phosphate; tricalcium phosphate.—*Dicalcium phosphate,* an excellent phosphorus supplement with a safe level of fluorine, is usually made from rock phosphate or phosphoric acid, but some is made from bones. It has 18 per cent or more of phosphorus, in comparison with 14.5 per cent for bone meal. Per pound of phosphorus, dicalcium phosphate equals bone meal as a phosphorus supplement.[23]

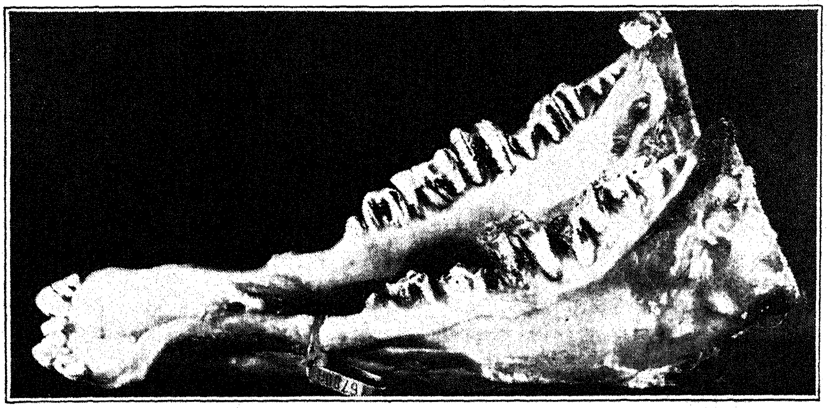
Monocalcium phosphate is a similar product, except that it has more phosphorus and much less calcium. *Tricalcium phosphate,* on the other hand has more calcium than does dicalcium phosphate.

167. Soluble phosphate added to water; phosphoric acid.—In areas where the salt content of the forage is higher than usual, livestock on pasture may consume but little common salt. When phosphorus supplements are mixed with salt, they may then not eat the desired amount of the mixture, and the phosphates are often not palatable when fed alone. Under such conditions, sometimes sodium phosphate or another soluble phosphate is added to the drinking water in the proper amount.[24]

In a recent Kansas test liquid phos-

phoric acid, added to molasses, was a satisfactory phosphorus supplement for beef cattle or sheep.[25] As phosphoric acid is corrosive, the small amount needed must be carefully mixed with suitable feeds.

168. Poisonous effects of fluorine.—Traces of the mineral fluorine are apparently needed by animals for the development of teeth of good quality, and these traces are amply supplied by all ordinary rations. In livestock feeding, we are concerned only with the poisonous effects of fluorine when dangerous amounts are consumed.



FLUORINE IN CERTAIN ROCK PRODUCTS MAY POISON STOCK

Jaw bone and teeth of cow which had been fed a mineral supplement containing fluorine for three years. The teeth were worn down to such an extent that the cow was unable to chew her feed normally. In spite of liberal feeding she became a pitiful wreck. (From Udall, New York State Veterinary College, Cornell University.)

Not only is fluorine a violent poison when taken into the body in any considerable amount, but it is also a cumulative poison. Even very small amounts have a poisonous effect if steadily consumed over a long time. The chief effect is upon the teeth and bones. The teeth have faulty enamel and are so soft that they wear down so much that the animals are unable to chew their food. In some cases the teeth are worn down to the pulp cavities and are so sensitive that the animals will not drink cold water, because of the pain, but lap it with the tongue, like cats or dogs. The bones become soft and are often enlarged, and the animals may become lame and have difficulty in walking.

In addition to these effects, animals suffering from fluorine poisoning may have poor appetites, and sometimes serious diarrhea. Young animals fail to gain normally, older ones lose weight, and milk production is much decreased.

Serious fluorine poisoning of stock, especially cattle, has occurred in a few areas where the water or soil was unusually high in fluorine, and also in the vicinity of certain smelters or factories where fluorine-containing flue gases have contaminated the soil and forage.

Several experiments have been conducted to determine the effects upon different classes of stock of rations containing various amounts of fluorine, the most extensive being the studies of Hobbs and associates at the Tennessee Station.[26] In the Tennessee experiments the teeth of cattle became worn and eroded when the animals were fed continuously rations containing 0.0037 per cent (37 parts per million) or more of fluorine.[27] Even less caused marked staining of the teeth. In these studies the injurious effect of fluorine was decreased if 0.1 to 0.5 per cent of aluminum sul-

fate or aluminum chloride was included in the ration.

Sheep or swine are not injured by fluorine unless the level is higher than would be detrimental to cattle, and poultry are still less susceptible to fluorine toxicity.

169. Safe levels of fluorine in rations.—Since fluorine is a cumulative poison, the amount that will be safe in a ration for any class of stock will depend on how long the feeding of the supplement is continued. Thus, in Wisconsin experiments with dairy cows, including 0.6 per cent of rock phosphate in the concentrate mixture produced marked poisonous effects only after 3 years of continuous feeding.[28] Then the results were very injurious.

The Committee on Animal Nutrition of the National Research Council has recently recommended that total rations should not contain more than the following percentages of fluorine from a rock source: Dairy cows, 0.006–0.010; beef cows, 0.0065–0.010; sheep and swine, 0.010–0.020; and chickens, 0.030–0.040.[29]

If a supplement containing fluorine, such as rock phosphate, is fed for only a short period, a somewhat higher level of fluorine is not injurious.

Total rations should not have more than the following percentages of fluorine in soluble compounds, which are more readily absorbed: Dairy cows, 0.003; beef cows, 0.004–0.005; sheep and swine, 0.007–0.010; chickens, 0.015–0.030; and turkeys, 0.030–0.040.

The Association of American Feed Control Officials has adopted the following tentative regulation for any mineral or mineral mixture: "The fluorine content of any mineral or mineral mixture which is to be used directly for the feeding of domestic animals shall not exceed 0.30 per cent for cattle; 0.35 per cent for sheep; 0.45 per cent for swine; and 0.60 per cent for poultry." [21]

In using a phosphorus supplement of rock origin or a mineral mixture containing such a product, one should note the guarantee of the manufacturer concerning the fluorine content. He should be sure that the fluorine content of the total ration fed does not exceed safe limits.

Bone meal contains about 0.03 to 0.04 per cent of fluorine, an amount that is entirely safe when the usual amount of bone meal is fed as a phosphorus supplement.

The application of phosphate fertilizers in ordinary amounts for many years does not apparently increase the fluorine content of forages to a dangerous level.[30]

170. Iodine; goiter in farm animals.—Iodine is necessary for animals, because the rate of metabolism of the body is controlled through the action of an iodine-containing hormone, called thyroxine, which is secreted by the thyroid gland in the neck. If an animal does not secure enough iodine in its food to make a normal amount of this compound, the thyroid gland may enlarge in an attempt to make sufficient of it, and the ordinary type of goiter results.

Only very small traces of iodine are needed by animals, and the bodies of mature animals have less than 1 part of iodine in 3 million parts of body weight. In the case of farm animals a deficiency of iodine is apt to cause goiter only in the new-born young. Older farm animals rarely show any symptoms of a lack of this mineral.

It is now well known that the soil and water in certain areas of this and other countries are so deficient in iodine that additional iodine must be supplied to prevent goiter in man or in livestock. In other regions the iodine supply is ample, and there is no benefit whatsoever from furnishing additional iodine. In the United States the chief iodine-deficient areas are in the Great Lakes region and westward toward the Pacific Coast.

Generally, iodine deficient areas are found only in interior districts, and the iodine supply is ample in most sea-coast regions. This is because sea water is rich in iodine. Ocean spray carried into the air evaporates, and the sea-salt dust is brought inland by wind.

Before the method of prevention was discovered, there were heavy losses

of new-born pigs, lambs, kids, calves, and foals in iodine-deficient areas, because of goiter. The young thus affected are born dead or weak, the losses being especially severe in the case of pigs and lambs. Such pigs usually are practically hairless, and the disease in swine is often called "hairless pigs." The pigs have thick, pulpy skin and large necks, and seem unusually large and fat because of a bloated condition. In lambs and calves affected with goiter, the enlarged thyroid gland is readily seen. In foals there is seldom a visible goiter, the only symptom usually being extreme weakness at birth.

Experiments have proved conclusively that goiter in new-born farm animals can be entirely prevented by supplying small amounts of iodine to pregnant animals during at least the last half of the pregnancy period.[31] The simplest method of furnishing iodine is to supply iodized stock salt during this period, instead of ordinary salt. Such salt should contain 0.007 per cent of iodine, and a process should be used to stabilize the iodine so as to prevent its loss into the air. Otherwise, on exposure much of the iodine will be volatilized.

If iodized salt is not readily available, it can be mixed on the farm by adding one-half ounce of finely-ground potassium iodide to 300 lbs. of salt. The mixture will contain a little more than 0.007 per cent iodine. Because of the small amount of potassium iodide used, it should be first mixed thoroughly with a few pounds of the salt, and this then be mixed with the rest of it.

In areas where iodine deficiency is most serious, it may possibly be wise to use iodized salt regularly in place of common salt for all stock, and not merely for pregnant animals. On the other hand, in districts where there is no deficiency of iodine, the use of iodized salt or other iodine supplements for farm animals does not seem advisable. Experiments have shown that an excess of iodine is definitely injurious to animals. Organic forms of iodine, such as kelp, are no more effective than iodized salt for preventing goiter. (977)

Certain drugs, especially thiouracil and thiourea, decrease the action of the thyroid gland and thus slow down metabolism. It is of interest, but not ordinarily of practical importance, that cabbage, turnips, and soybeans seem to

GOITER SOMETIMES CAUSES HEAVY LOSSES

A litter of pigs affected with goiter, or "hairlessness," caused by a lack of iodine in the ration of the sow. Some of the pigs are dead, while others are still alive, although very weak. After this sow had been given iodine in the form of potassium iodide during her next gestation period, she produced a litter of thrifty pigs. (From Hart, Wisconsin Station.)

have a similar effect on the thyroid gland. Thiouracil has sometimes been used to increase the rate of fattening of animals.

171. Iodine supplements in borderline areas.—It is rather surprising that there is but little goiter among livestock in many areas where it has been common among humans. Thus, there have been few cases of goiter in livestock in certain areas east of the Mississippi River where goiter is frequent in humans unless iodized salt is used.

Where the supply of iodine is rather low, but not deficient enough to cause noticeable goiter in new-born animals, the use of iodized salt may be beneficial. For example, using iodized salt instead of common salt for brood sows in a New York experiment reduced the number of pigs born weak or dead, although there had been very few cases of new-born pigs showing symptoms of goiter.[32]

Anyone who is in doubt as to whether or not it is advisable to use iodized salt in place of common salt for his stock under his local conditions can readily secure information from his state agricultural college or county agent.

A very limited amount of data indicates that navel-ill and weakness of foals may be lessened by feeding brood mares during pregnancy as much as 14 to 15 grains of potassium iodide a week, with their grain.[33] Further results are needed before final conclusions can be drawn concerning the merits of this treatment.

In areas where there is no definite deficiency of iodine for livestock, there has generally been no benefit from adding iodine to a normal ration. Several experiments have been conducted to study this question, including trials with dairy cows, dairy calves, pigs, lambs, and chickens.[34] Even in the trials where an iodine supplement has apparently been beneficial, the advantage has usually been slight.

In spite of these results, extravagant advertising claims are sometimes made for various iodine supplements. For example, statements have been made that such products will build up resistance to various diseases, will prevent sterility and other breeding troubles, will eradicate or prevent brucellosis (Bang's disease), will cause a great increase in product, or will markedly increase the efficiency with which feed is utilized.

172. Iron and copper.—An adequate supply of iron is necessary for animals, because the oxygen is transported in the blood by the hemoglobin, which is an iron-containing compound. Iron also has other necessary functions in the body. In spite of the importance of iron, the bodies of animals contain only a very small amount. Indeed, there is only 0.01 to 0.03 per cent of iron in the bodies of farm animals.

For hemoglobin formation there must be small traces of copper in the food, as well as an ample supply of iron, although hemoglobin contains no copper. Traces of copper are therefore necessary for animals, although this mineral is a violent poison when any considerable amount is taken into the body.

The amount of copper required by animals is very small, being only about one-tenth the requirement of iron, or even less. Where the need for copper is not increased by an excess of molybdenum or some other condition, a content of only 0.6 part of copper per million in the dry matter of forage is all that animals need. (173)

If the food of animals is too low in iron, or in copper or cobalt, nutritional anemia will result. In this disease there is a serious lack of hemoglobin in the blood. Such anemia is very different from pernicious anemia in man and from anemia caused by great loss of blood, as from a wound. At least in the case of some animals, anemias may also be caused by a deficiency of certain vitamins.

In all but very few areas of the world, the usual rations of farm animals supply an abundance of iron and copper, except perhaps during the suckling period, as is explained later in this chapter. With this exception, there is generally no need of adding copper or iron supplements to livestock rations.

In a few districts the soil is so lack-

ing in copper that serious disease is produced in livestock. Copper deficiency in cattle or sheep causes slow growth, failure to fatten, and severe anemia in extreme cases. In young cattle, a rickets-like condition may result and the bones may become fragile. Cows in a copper-depleted condition may fail to conceive or may have difficulty in calving, and the calves may be born rachitic. In copper deficiency, the hair of the cattle becomes bleached in color, and wool loses its natural crimp, but instead is straight and "steely." Where there is a deficiency of copper, the lack can readily be corrected by the use of such a mineral mixture as the "salt sick" mineral mixture widely used in Florida. (173)

A deficiency of copper is believed to be the cause of the trouble of sheep in West and South Australia called "stringy" or "steely" wool, of the disease of sheep in West Australia called "enzootic ataxia," and of "falling disease" or "sudden death" of dairy cattle in West Australia. "Coast disease" of cattle and sheep in Australia and other areas seems to be due to a deficiency of both copper and cobalt.

Some scientists doubt that a deficiency of iron ever occurs under natural conditions in livestock past the suckling age. However, on mineral-deficient soil at the Florida Range Experiment Station, when iron has been omitted from the mineral mixture for beef cattle, the results have not been so good as with an iron supplement.[35]

Using an iron or copper supplement when it is not needed may be injurious. An excess of iron tends to interfere with the absorption of phosphorus, through the formation of insoluble iron phosphates. Animals may be poisoned by the continued use of a mineral or salt mixture containing a far greater amount of copper than the mere trace needed by animals.

Sometimes medicated stock salt or mineral mixtures containing appreciable percentages of copper sulfate are sold as preventives of stomach worms or other internal parasites. It was found in Texas studies that heavy losses of sheep on certain ranches were due to the continued use of such medicated salt mixtures.[36]

With the exception of milk, nearly all common feeds have sufficient iron to meet the need of farm animals, even though the iron content is usually less than 0.01 per cent. Leafy forages, legume seeds, wheat bran, meat and fish by-products, and most oil meals are higher than the grains in iron, but the grains generally have enough. There is but little information concerning the actual availability of the iron in various feeds to farm animals, as nearly all such studies have been chemical tests or trials with small laboratory animals.

173. Correcting copper and other deficiencies.—The largest area in this country where copper deficiency occurs is in Florida. For many years it had been known there that cattle would not thrive on certain areas of poor, sandy land. They lost their appetites, they became emaciated and weak, and their blood was very low in hemoglobin. Young cattle were most affected and were often badly stunted. Many of the animals died from the disease, which is called "salt sick." Goats and sheep were also affected in certain of the areas.

It was finally found that these conditions were due to a serious lack in the forage of one or more of the trace minerals, including copper.[37] In certain areas, the chief deficiency is of cobalt, which is discussed later. Often the lack of trace minerals is associated with a deficiency of phosphorus or calcium, or of both of these minerals.

Recovery follows rapidly when the animals are allowed to take as much as they wish of a "salt sick" mineral mixture, such as the following: 100 lbs. common salt, 25 lbs. red oxide of iron, 1 lb. pulverized copper sulfate, and 1 ounce cobalt sulfate or cobalt chloride. One-half ounce cobalt carbonate may be used instead of the sulfate or chloride, as it is twice as high in cobalt. The mixture must be mixed very thoroughly, so no animal will get too much copper sulfate or cobalt, as they are poisonous if consumed in more than traces. In the areas

where the forage is also deficient in phosphorus or calcium, it is necessary to include these minerals also in the mixture.

In certain areas nutritional diseases occur that are prevented and cured by a copper supplement, even though the forage has a normal amount of copper. However, the assimilation and utilization of copper is prevented by an excess of another mineral or by some unknown cause.[38]

Investigations in England of the disease called "teartness" first revealed the cause of this trouble which occurred in ruminants, especially in calves and cows in milk. Animals suffering from this disease have serious diarrhea and run down in condition. It was found that although the pasture forage had a normal amount of copper, the animals were suffering from a copper deficiency, caused by a high content of molybdenum. The trouble could be entirely corrected by supplying a copper supplement. (Molybdenum is a mineral that is required in mere traces by plants.)

Other areas have since been found where this trouble, caused by excess molybdenum, occurs. Among these are a considerable district in southern Florida on organic soil, areas in southern California, and one in Manitoba, Canada.[39] Cattle are most frequently affected, especially young animals. Sometimes sheep are injured, and also even horses, swine, and chickens.

The amount of copper needed in a mineral mixture to prevent the disease will depend on the molybdenum content of the forage. Advice should therefore be secured from the local agricultural college or experiment station as to the proper mineral mixture to use in any particular area. In the Everglades district of Florida, the following mixture is recommended: Steamed bone meal 50.0 lbs., common salt 44.7 lbs., pulverized copper sulfate 2.5 lbs., copper oxide 0.8 to 1.2 lbs., depending on the copper content, and cobalt carbonate 1.0 ounce or cobalt sulfate or chloride 2.0 ounces. (Copper oxide is used to furnish part of the copper, as it is less soluble and less toxic than copper sulfate. Two pounds of aluminum sulfate is sometimes added to the mixture but is not considered necessary.)

Another copper deficiency disease that occurs with a normal amount of copper in the forage is "swayback" of new-born and young lambs, which occurs in several areas in Great Britain. The lambs suffer from incoordination or paralysis of the legs and often die. The trouble can usually be prevented by feeding a copper supplement to the ewes during pregnancy. This can be done by mixing 0.3 lb. of copper sulfate with each 100 lbs. of salt. The forage in these areas is generally normal in copper content, but it is apt to have an unusually high content of lead and zinc, which apparently interferes with the utilization of the copper in the feed. "Copper pine" of calves also occurs in some areas of Scotland with a normal content of copper in the forage, and no excess of molybdenum.[40]

174. Anemia of suckling animals.—Milk is exceedingly low in iron and also in copper, and it is not possible by any method of feeding the mother to increase the amounts of these minerals in her milk. To offset this lack, young mammals are born with a store of the minerals in their bodies which normally suffices until they begin to eat other food that supplies plenty of these minerals. If they are kept on milk alone for an unusual length of time, disaster will follow because of these and other lacks.

When young farm animals are raised under normal conditions and are allowed to eat other feed as soon as they will take it, there is generally no trouble whatsoever from anemia (the lack of hemoglobin), except in the case of suckling pigs which are not on pasture but are confined away from the soil. Anemia may readily be prevented in such suckling pigs by one of the methods described in Chapter XXXIV.

175. Cobalt.—In 1935 it was first reported that certain serious diseases of grazing stock in Australia were definitely caused by a deficiency of cobalt in the

feed.[41] Since then, in widely-scattered areas of the world, it has been proved that lack of cobalt or of both cobalt and copper is the cause of hitherto baffling diseases of ruminants.

In North America, it has been determined that a lack of cobalt has produced serious troubles in certain areas of Florida, Maine, New Hampshire, Michigan, New York, Wisconsin, and Western Canada.[42] However, cobalt-deficiency is distinctly a local problem, and in most of our country there is apparently no lack of cobalt in livestock feeding.

after cobalt is supplied. It is sometimes difficult to distinguish the symptoms of cobalt deficiency from those caused by a lack of phosphorus. However, if the appetite is not improved decidedly after 2 weeks of cobalt feeding, the trouble is not due to cobalt deficiency. In this way, one can readily find whether a cobalt deficiency is actually the cause of the malnutrition in his stock.

Cobalt is required by the bacteria which are so important in the digestion of feed and the synthesis of B-complex vitamins by ruminants. It is believed that the chief cause of cobalt-deficiency trou-

THE PIG ON THE LEFT HAS SEVERE ANEMIA

These pigs are litter mates. The one on the left was raised by its mother in a hog house and a small paved exercise lot, without access to the soil. It has severe anemia, due to the lack of iron and copper in milk. The thrifty pig on the right was transferred soon after birth to a sow whose udder was swabbed with a solution of ordinary iron sulfate. (From J. P. Willman, Cornell University.)

In cobalt-deficient areas, the trouble occurs both with stock on pasture and with animals fed winter rations. Young animals are more apt to be affected than mature ones.

Cattle or sheep suffering from cobalt deficiency lose their appetites, become unthrifty and emaciated, and may have a depraved appetite, especially a desire to eat hair or gnaw wood or bark. A serious anemia may also be produced. Young animals fail to make proper growth, and in severe cases animals may "pine away" and die. On some farms affected by the trouble, a considerable proportion of the lambs have been lost because of this deficiency.

Cobalt-deficient animals usually show marked improvement in appetite and other conditions within 3 to 7 days

bles in ruminants is a lack of vitamin B_{12}, produced by a greatly lessened formation of this vitamin in the rumen when there is a serious lack of cobalt in the food. Cobalt-deficiency in sheep has been cured by feeding or by hypodermic injection into the blood of sufficient amounts of vitamin B_{12}.[43]

These discoveries explain why non-ruminants need less cobalt than do ruminants. Horses, on the same pastures where cattle suffer from cobalt deficiency, are not affected. However, even non-ruminants, such as swine and poultry, need minute traces of cobalt, because vitamin B_{12}, which they require, contains cobalt. (220) In recent experiments adding cobalt to low-cobalt rations for growing pigs has increased the gains.

Only mere traces of cobalt are required by cattle and sheep, a content of 1 part of cobalt in 10 million parts of the ration, on the dry basis, providing an ample amount. The requirement for sheep seems to be slightly higher than for cattle. Sheep show definite symptoms of cobalt deficiency when pasture forage has less than about 0.7 part per 10 million, on the dry basis, while cattle may not suffer until the content is 0.4 part per 10 million parts. Before the cause of the disease was discovered, farmers had found that it could be cured by moving the affected animals from the "sick" area to a "healthy" pasture. Investigations showed later that the recovery on "healthy" areas was due to a higher cobalt content of the forage.

Legume forage generally has more cobalt than do the grasses, but yet may sometimes be deficient. Timothy seems to be often especially low in cobalt. Recent studies have shown that heavy fertilization of soil rather low in cobalt with ordinary complete fertilizer may reduce the cobalt content of forage, because of the heavy crop yields.[44]

In cobalt-deficient areas trouble from the lack of cobalt can be prevented by mixing 1.0 ounce of cobalt sulfate or cobalt chloride, or else 0.5 ounce of cobalt carbonate, in each 100 lbs. of salt. In order to mix this very small amount of cobalt salt thoroughly with the common salt, it is best to dissolve it in a little water, spray it over the salt with a small fly sprayer, and then mix the salt well. Thorough mixing is essential, so that no animal will get a large excess of cobalt, which would be injurious. In cobalt-deficient regions, the needed trace of cobalt is rather generally added by the manufacturer to commercial formula feeds.

Although an animal can be poisoned by a considerable amount of a cobalt salt, no injury is produced by a ration that contains one hundred times the amount actually needed.[45]

Where there are deficiencies of copper or iron in addition to cobalt, such a mixture as the "salt sick" mineral mixture used in Florida should be fed. (173) In an area where the salt content of the pasture forage is so high that the animals do not eat much salt, as in some areas of Scotland, 3 lbs. of cobalt sulfate per acre can be mixed with superphosphate and applied to the pasture.

For animals already seriously affected by cobalt deficiency, it may be necessary to administer cobalt as a drench. For mature cattle a suitable treatment is 1 tablespoonful per day of a solution of 1 ounce of cobalt sulfate in 1 gallon of water, for a week or two, after which the cobalt can be supplied in the salt. For very young calves 2 teaspoonfuls of this solution per day can be added to the milk for the first couple of weeks.

EFFECTS OF COBALT DEFICIENCY

Left, yearling heifer suffering from severe cobalt deficiency on cobalt-deficient pasture. Right, the same heifer 2 months before freshening and 7 months after she had been supplied with a "salt-sick" mineral mixture containing cobalt, on the same pasture. The heifer showed marked recovery within 2 months after cobalt was supplied. (From Becker, Florida Station.)

Except in areas where a cobalt deficiency is known to exist, or where symptoms strongly indicate such a deficiency, there is no advantage in adding cobalt to salt or to a mineral mixture. A normal appetite for feed shows that animals are getting sufficient cobalt in their usual rations.

A lack of cobalt or a combined deficiency of cobalt and of copper and perhaps iron has been found to be the cause of "salt sickness" in cattle and sheep in Florida. Cobalt deficiency is the cause of "bush sickness" and similar diseases of sheep and cattle in certain areas of New Zealand and Western Australia. The "pining disease" of sheep in some districts of Scotland and England is usually due to cobalt deficiency, while the "coast disease," which affects cattle, sheep, and goats in South Australia and certain other regions, is apparently caused by a lack of both cobalt and copper.

176. Sulfur.—Sulfur is necessary for animals, because it is an essential part of most proteins and also of certain vitamins and other compounds needed in the vital processes of the body. In proteins, sulfur occurs in methionine, one of the essential amino acids, and also in cystine, which can partially replace methionine in function.

Fortunately, animals need but a very small amount of sulfur in their food, and plenty is apparently furnished by nearly all well-balanced rations. Sheep require more sulfur than do other farm animals, because wool is high in cystine, having about 4 per cent. However, in a Canadian experiment with ewes, there was no benefit from adding sulfur to a low-sulfur ration that had only 0.08 per cent sulfur.[46] In an Oregon trial with dairy cows, there was no advantage in adding sulfur to a low-sulfur ration which had 0.1 per cent sulfur.[47]

Most rations supply more than these amounts of sulfur.[48] However, in a few areas, as in certain districts of the northwestern coast states, the soil is so low in sulfur that the yield and also the sulfur content of legume forage crops are much reduced, unless a sulfur fertilizer is applied. In an Oregon experiment, lambs fed such low-sulfur alfalfa hay gained considerably less than did others fed alfalfa from a sulfur-fertilized plot.[49]

It was formerly believed that animals had little, if any, ability to use sulfates or free elemental sulfur for making the sulfur-containing amino acids. Recent experiments have proved, however, that ruminants fed a low-sulfur ration can use sulfates and even free sulfur for this purpose to a limited extent, though such sulfur may be less effective than that supplied by methionine.[50] Such synthesis of simple forms of sulfur into the sulfur-containing amino acids probably comes about through the bacterial action in the rumen. However, even chicks can apparently use some sulfate sulfur for protein formation when added to a low-sulfur ration.[51]

It has been shown in Chapter V that the protein in certain common feeds, especially some legume seeds, is low in methionine and cystine, and therefore is inefficient for non-ruminants unless this lack is corrected. (**122**)

Adding finely powdered sulfur to a poultry mash tends to prevent coccidiosis, but such addition greatly increases the vitamin D requirement. It is therefore detrimental unless the birds have an abundant supply of this vitamin. Claims have been made that the feeding of sulfur or sulfurized salt to cattle would repel lice or flies, but there was no such effect in Texas and Kansas tests.[52]

177. Potassium.—Potassium is essential for animals, and the bodies of animals contain more potassium than they do of either sodium or chlorine. However, the usual feeds supply ample amounts of potassium, and there is no need of adding potassium supplements to livestock rations.

Very heavy fertilization with potassium may greatly increase the potassium content of forage crops and reduce the calcium so much that a calcium supplement is needed by dairy cows or other stock.[53]

It has been a disputed point as to whether or not the presence in a ration of a considerable amount of potassium

will cause an increased excretion of sodium, and therefore a greater need for common salt.[54] Though this often does not seem to be the result, nevertheless herbivora, living largely on forage plants, which are generally high in potassium, require more salt than swine and poultry, which consume rations rather lower in this mineral.

178. Magnesium.—Magnesium is present in very small amounts in the bodies of animals, forming only from 0.02 to 0.05 per cent of the bodies of farm animals. Nevertheless, it is necessary for life. If experimental animals are fed rations from which the magnesium has been removed as completely as possible, they will show increasing irritability after a few days and a little later die in convulsions.

Most normal feeds contain the small amounts of magnesium that are necessary for animals. Therefore, there is generally no lack of it in any ordinary ration fed livestock.

In experiments to determine magnesium requirements, only 0.06 per cent has been needed by dairy calves, 0.04 per cent by chicks, and 0.05 per cent by ducks.[55] Most feeds have much more magnesium than this. For example, alfalfa hay has 0.29 per cent and corn grain 0.10 per cent. (Appendix Table IV.)

When whole milk is fed to calves as the only food for an unnaturally long period, it is apparently necessary to add a magnesium supplement, as well as iron and copper.

It was formerly believed that magnesium had a decidedly antagonistic action toward calcium in the body, and that an excess of magnesium would cause a large loss of calcium, thus producing injury. More recent experiments have shown, however, that unless the excess of magnesium is very large, no bad results will be produced, provided that the ration has an ample supply of calcium and phosphorus. As has been stated earlier in this chapter, dolomitic or magnesian limestone is fairly satisfactory as a mineral supplement, except for poultry. (157)

179. Grass tetany; wheat or oat pasture poisoning.—A serious disease, called grass tetany or grass staggers, in which the blood has a very low content of magnesium and often also of calcium, has been reported from many parts of the world.[56] It occurs chiefly in milking cows, often shortly after calving, and in lactating ewes, but has also been reported in dry cows, steers, and calves. It frequently appears soon after the animals are turned to pasture in the spring. The usual symptoms are nervousness, lack of appetite, rapid breathing and pulse rate, and finally convulsions and coma, often ending in death. The poisoning that sometimes occurs on young wheat or oat pasture seems to be similar to or the same as grass tetany.

The exact cause of the disease has not been determined. Sometimes the forage is low in magnesium, but in other cases the content is normal. The most commonly used treatment is the hypodermic injection of a solution of calcium gluconate, with or without the addition of glucose, magnesium, or phosphorus.[57] If the animal is not treated before it loses consciousness, there is little chance of recovery. In some cases the feeding of a magnesium supplement, or providing dry feed in addition to pasture, has apparently aided in preventing the trouble.

180. Manganese.—Manganese is essential for animals and also for plants, but only mere traces are needed. All ordinary feeds have small amounts of manganese, and most rations apparently furnish plenty for all classes of stock except poultry, which have unusually high requirements for it.

Claims have been made that manganese or other trace mineral supplements will prevent or cure brucellosis (Bang's disease) in cattle. However, in Wisconsin, Ohio, and Missouri experiments such supplements have had no such effect.[58]

The special needs of manganese by poultry for the prevention of perosis, or "slipped tendon," and for hatchability of eggs are discussed in Chapter XXXVI. The small amount of manganese needed, even by poultry, is shown by the fact

that the addition of only one-quarter pound of manganese sulfate per ton of poultry mash provides insurance against a deficiency of the mineral.

Symptoms of manganese deficiency have been produced in rats and rabbits by feeding them highly-purified experimental rations containing practically no manganese. In rats a deficiency of manganese lessens growth, produces poor bones, and impairs reproduction and lactation. In rabbits it causes weak bones and crooked legs.

The manganese requirements of swine have been investigated by using purified rations exceedingly low in the mineral, or rations having an unusually low manganese content. From Wisconsin trials it was concluded that swine need 25 to 30 parts of manganese per million parts of feed for optimum growth and best reproduction.[59] In a Florida experiment a ration having only 3 parts per million of manganese depressed early growth, and sows raised on this ration produced weaker pigs than did those receiving more manganese.[60] However, in Arkansas and Indiana studies pigs grew normally on rations extremely low in manganese, having only 0.5 to 1.5 parts per million.[61]

A considerable excess of phosphorus in a ration interferes with the utilization of manganese, because of the formation of compounds in which the manganese is unavailable. Apparently for this reason, in Pennsylvania experiments pigs developed stiffness and crookedness of the legs and enlarged hocks on rations containing considerable low-grade tankage, which was very high in bone.[62] Adding a manganese supplement to the ration prevented the trouble, but did not cure it after it had developed.

In Indiana studies with dairy calves, the growth rate was a trifle less and sexual maturity was delayed on a ration having only 6 to 8 parts of manganese per million, in comparison with higher levels.[63]

Most hays have 20 or more parts of manganese per million. The grains are lower, as a rule, corn being especially low. Wheat bran, wheat middlings, and rice bran are particularly high in manganese.

181. Zinc.—Very little information is available concerning zinc in animal nutrition. Experiments with rats fed highly purified diets, freed as thoroughly as possible from zinc, have shown that traces of it are necessary for good growth and also for normal hair development.[64]

It has just been found in experiments that adding a zinc supplement to a ration helps prevent and cure parakeratosis in swine, a skin disease that somewhat resembles mange but is apparently of nutritional origin.[65] A ration that has an excessive amount of calcium supplement seems to increase the trouble.

In swine herds where parakeratosis has been prevalent, it is recommended that 0.5 lb. of zinc carbonate or 1.0 lb. of zinc sulfate should be added per ton of the feed mixture. This should be discontinued about 2 weeks before the swine are sold for slaughter.

With this exception, there is no need of adding a zinc supplement to any ordinary ration, so far as we know. Claims have been made that a zinc supplement will increase the length of life of farm animals, but the author has seen no scientific evidence to this effect.

On account of the wide use of galvanized (zinc-coated) containers for liquids, studies have been conducted to find whether or not sour foods would dissolve sufficient zinc to be poisonous to animals. In Oklahoma tests buttermilk stored in galvanized tanks for some time was not poisonous to rats.[66] Probably most cases of poisoning attributed to zinc have been due to lead, which is present in most zinc coatings.

182. Charcoal; coal.—Wood charcoal or coal is sometimes included in mineral mixtures or added to concentrate mixtures, especially for swine or poultry. Charcoal consists chiefly of carbon in elemental form and supplies but little mineral matter. Its use is sometimes advocated as a corrective of diarrhea and an absorbent or adsorbent of gases and of detrimental decomposition products produced in the intestines.

However, several experiments with growing and fattening pigs have conclusively proved that adding charcoal or either hard or soft coal to an ordinary ration is not beneficial or economical.[67] In these trials more feed has usually been required per 100 lbs. gain on rations with added charcoal or coal than without such addition.

California experiments with chicks show that charcoal tends to absorb vitamins and hold them so that they are not available.[68] Therefore adding charcoal to a ration may produce a vitamin deficiency, unless the ration contains a greater supply of vitamins than the minimum amount ordinarily needed.

In New York experiments with chicks and with laying hens the addition of charcoal to the ration did not have any beneficial effect on growth, egg production, feed utilization, or mortality.[69] In cases of severe diarrhea the condition of the droppings was not influenced by charcoal, though there was some improvement in mild diarrhea.

183. Acid-base balance.—In the tissues, a proper balance must be maintained between the alkaline, or basic, compounds and the acidic compounds in the blood and other body fluids. Some minerals, such as phosphorus, chlorine, and sulfur, are acid in reaction, while others, such as calcium, sodium, potassium, and magnesium, are alkaline. The proportion of bases and of acid constituents in the food often varies widely. It is therefore fortunate that the body has much ability to maintain the neutrality of the blood in spite of considerable differences in the intake of alkalies and acids in the food.

Farm animals, especially ruminants, have great ability to produce ammonia in the body tissues to neutralize any ordinary excess of acid. Therefore, any amount of acid that may be present in an ordinary ration is not injurious, if the ration furnishes sufficient amounts of calcium and other essential minerals.

Organic acids, such as the lactic acid and acetic acid in silage, do not tend to produce an acid reaction in the body. If they are completely oxidized, they yield only carbon dioxide and water. For this reason, experiments have abundantly proved that the continued feeding of liberal amounts of corn silage to dairy cows for several years has no injurious effect whatsoever.[70] Also, cows, calves, and swine have been fed without harm greater amounts of dilute mineral or organic acids than would be contained in any normal ration.[71]

Only when silage preserved with phosphoric acid or other mineral acids is fed, is there usually any need of giving attention to the acid-base balance of the ration. In feeding such silage, ground limestone or a mixture of limestone and sodium bicarbonate should be added. (432)

184. Does apparent craving for minerals indicate deficiency?—When farm animals gnaw bones, wood, or other objects, or eat dirt, it often indicates a deficiency of phosphorus or some other mineral. (155) However, sometimes animals show such a tendency when there is no deficiency whatsoever. For example, horses often gnaw wooden mangers when they are in excellent health and are amply supplied with all nutritive essentials. When livestock display such tendencies, one should investigate the possibility of a mineral deficiency in their rations, and then correct any such lack.

That such a tendency does not always indicate a lack of a mineral is well shown by an interesting case at the National Institute for Research in Dairying in England.[72] Pigs eagerly licked and gnawed copper rings at the base of steel posts in the pens of the swine barn. A test was therefore conducted in which plates of various metals were placed in the pens. The pigs showed a tendency to lick only the plates of copper or copper alloy. It might have been supposed that this indicated a lack of copper in their feed. However, careful tests showed that there was no benefit from adding a copper salt to the ration.

185. Trace minerals; trace mineralized salt.—It has been shown previously in this chapter that in certain areas, and only in certain areas, deficiencies occur of one or more of the trace minerals—

iodine, copper, iron, cobalt, and manganese. The dramatic curing of serious livestock trouble by the use of a very small amount of a trace mineral has caused many stockmen to wonder whether they should not regularly supply their animals with a mixture of trace minerals as insurance against any possible deficiency.

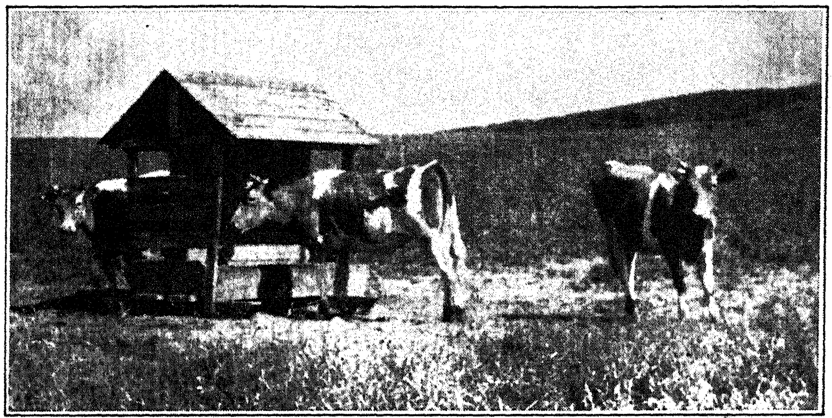
Some of the large salt companies are marketing trace mineralized salt to which the various trace minerals have been added. Trace minerals are also now included in many commercial mineral mixtures and formula mixed feeds.

It should be borne in mind that over much of our country there are no known deficiencies for the larger farm animals of any of the trace minerals. Where there is no deficiency of a trace mineral, money spent for trace mineral supplementation is wasted. If a stockman is in doubt as to whether or not it will be profitable for him to purchase a trace mineral supplement for his animals, the wise plan is to secure advice from his agricultural college, experiment station, or county agent.

In the chapters dealing with the various classes of stock, there are summarized the experiments in which the addition of trace minerals to ordinary rations has been tested. In Chapter XXXVI very recent experiments are summarized which indicate that for optimum growth chicks require an unidentified trace mineral or a combination of minerals, in addition to the previously known mineral needs.

186. Using simple mineral mixtures.—When a ration is fed that is deficient in calcium or in phosphorus, this lack should be corrected by the use of a suitable mineral supplement, as has been shown previously. When a mixture of ground concentrates is being fed, the proper amount of the mineral supplement may be mixed with the concentrates. In other cases, the mineral supplement is best mixed with salt to make it more palatable, and the mixture then placed in a suitable box or trough, where the stock can have access to it. The instinct of farm animals guides them to consume enough of the mineral mixture to correct the deficiency in the ration. In a humid region the mineral feeder should preferably be covered, to protect the contents from rain.

If the only deficiency is of calcium, such a mixture as 2 parts by weight of ground limestone or some other calcium supplement and 1 part of common salt is satisfactory. A mixture like this is very much cheaper than one that supplies phosphorus in addition. If phosphorus is deficient and there is plenty of calcium



A COVERED FEEDER PROTECTS MINERALS FROM RAIN

A convenient covered feeder for supplying cattle on pasture with salt and a mineral mixture. (From New York State College of Agriculture, Cornell University.)

in the ration, such a mixture as 2 parts or more by weight of bone meal or some other safe phosphorus supplement and 1 part common salt is excellent. It should be remembered that bone meal supplies both phosphorus and calcium, and contains twice as much calcium as it does of phosphorus.

If there is a decided lack of calcium in the ration and also a possible deficiency of phosphorus, then a combination of a calcium supplement with a phosphorus supplement like bone meal may be desirable. It has been emphasized in this chapter that for cattle, sheep, and horses, there is only rarely a deficiency of calcium, except in the case of fattening cattle or sheep fed non-legume roughage. Where there is probably no lack of calcium, it is unwise to use a mineral mixture that is high in calcium and relatively low in phosphorus.

Such a mixture as 4 parts by weight of steamed bone meal, 4 parts of ground limestone, and 2 parts of salt is often used for all classes of stock, but this supplies 4 times as much calcium as phosphorus. Unless there is a decided lack of calcium in the ration, a better mixture for cattle, sheep, and horses is a mixture of bone meal and salt, or such a combination as 60 parts by weight of steamed bone meal, 20 parts of ground limestone, and 20 parts of salt.

In using one of these mixtures, it is wise to supply common salt separately in addition, so that the animals will not have to consume more of the mineral mixture than they need in order to get sufficient salt. However, in an area where the forage, water, or soil has considerable salt, animals consume much less salt than usual. If salt is provided separately, they may then not take the needed amount of phosphorus or calcium supplement.

If no salt is supplied separately, a mineral mixture for cattle should contain one-half salt and a mixture for swine at least one-third salt. A suitable mixture for cattle, when no additional salt is provided, is 2 to 3 parts by weight of bone meal, 1 part ground limestone, and 3 parts common salt. A good mixture for swine is made up of equal parts by weight of these three supplements.

In areas where there is trouble from goiter in livestock, one-half ounce of potassium iodide should be included in each 300 lbs. of mineral mixture for pregnant animals, unless iodized salt is fed separately. In the localities where there is a deficiency of copper or cobalt, these minerals should be supplied, as previously advised.

187. Commercial mineral mixtures.—Many commercial minerals for the various kinds of stock are on the market. Some of these are composed entirely of the satisfactory phosphorus and calcium supplements, common salt, and often trace minerals. Others are more complex, containing in addition such substances as Epsom salts, Glauber's salts, sulfur, sodium carbonate, silicates, and charcoal.

In the experiments in which such complex mineral mixtures have been compared with more simple mixtures, the complex mixtures have generally been no better.

Before purchasing a commercial mineral mixture, one should note carefully the guaranteed content of various minerals, especially of phosphorus and of calcium. If his stock need chiefly a phosphorus supplement, it is uneconomical to buy a mineral mixture that has several times as much calcium as it has of phosphorus.

Because limestone and other calcium supplements are so much cheaper than bone meal or other safe phosphorus supplements, commercial mineral mixtures are apt to be relatively low in phosphorus. Some have 4 to 6 times as much calcium as phosphorus, and yet are sold at a high price. If the chief need of the animals is for additional phosphorus, the purchase of such a mineral mixture is not wise.

QUESTIONS

1. What are some of the vital functions of minerals?
2. Discuss the importance and use of common salt in stock feeding.
3. What use is made in range areas of the

ability of cattle and sheep to consume large amounts of salt without injury?
4. Why are calcium and phosphorus of especial importance in stock feeding? Why is there now more often a lack of these minerals than formerly?
5. How do the bones serve as a storehouse of calcium and phosphorus?
6. State the relative calcium content of the following: (a) Legume forage; (b) non-legume forage; (c) cereal grains and other seeds and their by-products; (d) milk; (e) meat scrap, tankage, and fish meal.
7. State the relative phosphorus content of each of the above groups of feeds.
8. Why is a calcium supplement advisable for swine and poultry, while it is not generally needed for cattle, sheep, or horses?
9. When may a lack of phosphorus occur in feeding the following: (a) Dairy cows; (b) beef cattle and sheep; (c) swine and poultry?
10. By what kind of stock is phytin phosphorus not well utilized?
11. For what kinds of stock is the calcium-phosphorus ratio important?
12. What is the cause of rickets? Describe its effects.
13. What are the effects on mature animals of a lack of calcium or phosphorus?
14. How do the symptoms of phosphorus deficiency and of calcium deficiency in dairy cows differ?
15. Name 5 satisfactory calcium supplements.
16. Name 4 safe phosphorus supplements.
17. Discuss the effects of fluorine on livestock.
18. What is the importance of iodine for farm animals? Would you feed an iodine supplement to stock in a non-goitrous area?
19. Explain why iron and copper are needed by animals. Which of these minerals is definitely deficient in certain areas?
20. What are the symptoms of copper deficiency?
21. Why is a copper supplement needed in certain areas where the forages have a normal copper content?
22. Why does anemia occur in suckling pigs?
23. What are the symptoms of cobalt deficiency? Has any definite deficiency of cobalt been found in your district?
24. From what sources do animals get nearly all of the sulfur they need?
25. How can ruminants use sulfates or free sulfur?
26. Is there a need for adding the following to the rations of any class of livestock: (a) Potassium; (b) magnesium; (c) manganese; (d) zinc; (e) charcoal?
27. What is grass tetany?
28. When is it necessary to give attention to the acid-base balance of feeds?
29. Does an apparent craving for minerals always indicate a deficiency?
30. Is there a need of trace minerals in your area? Which are apparently lacking?
31. State a satisfactory mineral mixture for use under each of the following conditions: (a) When only calcium is lacking; (b) when both calcium and phosphorus are lacking; (c) for cattle fed no additional salt, when both phosphorus and calcium are lacking.
32. Discuss the use of complex mineral mixtures.

REFERENCES

1. Murphy, Penn. Bul. 488.
2. Mitchell, Card, and Carman, Ill. Bul. 279.
3. Lewis, Burkitt, and Willson, Mont., Jour. Anim. Sci., 10, 1951, p. 1053; Dowe, Nebr. Quarterly, 2, 1953, No. 2.
4. Lamb et al., Mich., Jour. Dairy Sci., 17, 1934, pp. 233–241; Kuhlman, Weaver, Gallup, and Nalbandow, Okla., Amer. Soc. Anim. Prod., Proc. 1936; duToit, Malan, and Groenewald, S. Africa, Onderstepoort Jour. Vet. Sci. and Anim. Indus., 1, 1933, pp. 421–424.
5. Colovos, Keener, Tieri, and Davis, N.H. Buls. 394, 402, 409; Colovos, Keener, and Davis, N.H., Jour. Dairy Sci., 38, 1955, p. 627.
6. Bohstedt, Wis., Proc. 1955 Cornell Nutr. Conf. for Feed Manufacturers.
7. Heuser, Feeding Poultry, 2nd Ed., 1955, p. 22.
8. Kleiber, Goss, and Guilbert, Cal., Jour. Nutr., 12, 1936, pp. 121–153; Hart and Miller, Cal., Jour. Agr. Res., 55, 1937, pp. 47–58; Cal. Rpt. 1936–38; Beeson, Johnson, Bolin, and Hickman, Id. Bul. 266; Becker, Neal, and Shealy, Fla. Bul. 264; Eckles, Becker, and Palmer, Minn. Bul. 229; Eckles, Gullickson, and Palmer, Minn. Tech. Bul. 91; Knox and Watkins, New Mex. Bul. 287; Schmidt, Texas Bul. 344; Madsen and Nielsen, Utah, North Amer. Vet., 21, 1940, pp. 81–89; Hart, Beach, and Bailey, Wis. Bul. 389; Theiler, Green, and du Toit, Jour. Dept. Agr. (Union of South Africa), 8, 1924, pp. 460–504.
9. Kleiber, Goss, and Guilbert, Cal., Jour. Nutr., 12, 1936, pp. 121–153; Riddell, Hughes, and Fitch, Kan. Tech. Bul. 36; Eckles and Gullickson, Minn., Amer. Soc. Anim. Prod., Proc. 1927.
10. Kennard and Chamberlin, Ohio Bimo. Bul. 230.
11. Hostetler and Nance, N.C. Rpt. 1932; Ohio Bul. 417; Tully and Franke, S.D. Bul. 287; Hart, Wis. Bul. 388; Ross, Weir, Bohstedt, and Phillips, Wis. Bul. 455.
12. Kennard, Ohio Bimo. Bul. 226; Miller and Bearse, Wash. Bul. 320.
13. Mehrhof and Rusoff, Fla. Rpt. 1942; Miller and Bearse, Wash. Bul. 320.

14. Edin and Anderson, Central Inst. Res., Stockholm, Sweden, Rpt. 476, 1937; Fangauf and Bruninghaus, Archiv. für Geflügelk., 9, 1935, pp. 180–184.
15. Scholes, Poultry Sci., 24, 1945, pp. 53–55.
16. Brophy and Sheehy, Irish Free State Dept. Agr. Jour., 38, 1941, pp. 387–390.
17. Ga. Rpt. 1940; Shrewsbury and Vestal, Ind. Rpt. 1937.
18. Heuser, Feeding Poultry 2nd Ed., 1955, p. 113; Tyler and Willcox, Jour. Agr. Sci., England, 32, 1942, pp. 43–61.
19. Fletcher, Miss. Information Sheet 489.
20. Heuser, N.Y., information to the author.
21. Assoc. of Amer. Feed Control Officials, Official Publication, 1956.
22. Becker, Davis, et al., Fla. Bul. 401; Ga. Rpt. 1944; Beeson, Hickman, et al., Id. Buls. 264, 268; McConnell, Insko, and Buckner, Ky. Bul. 455; Gullickson and Olson, Minn., Jour. Dairy Sci., 26, 1946, pp. 317–320; Barrentine, Maynard, and Loosli, N.Y., Jour. Nutr., 27, 1944, pp. 35–42; Gillis, Norris, and Heuser, N.Y., Jour. Nutr., 52, 1954, pp. 115–125; Williams, MacLeod, and Morrell, Tenn. Cir. of Inf. 70, and Sup. 1; Evans and Carver, Wash. V Cir. 6; Clark, Weakley, and VanLandingham, West Va. Bul. 317; Ellis and Cabell, U.S.D.A., Jour. Anim. Sci., 3, 1944, p. 446.
23. Davis, Arrington, and Outler, Fla., Jour. Anim. Sci., 12, 1953, p. 913; Massey and Fisher, Ga. Cir. 157; Hodgson, Johnson, Wiese, and Hickman, Id., Jour. Anim. Sci., 7, 1948, pp. 273–278; Knox and Meade, New Mex. Bul. 249; Maynard and Rottensten, N.Y. (Cornell) Rpt. 1934; Tenn. Rpt. 1936; Maynard and Greaves, Utah Bul. 276; Newlander, Ellenberger, and Jones, Vt. Bul. 406; Mather, Pratt, and Holdaway, Va., Jour. Dairy Sci., 32, 1949, pp. 228–236.
24. Reynolds, Jones, Jones, Fudge, and Kleberg, Tex. Bul. 773.
25. Menzies, Richardson, Baker, and Cox, Kan., Jour. Anim. Sci., 14, 1955, p. 1217.
26. Reviews of the investigations on fluorine toxicity are given in Hobbs et al., Tenn. Bul. 235, 1954; Mitchell, Nat. Res. Council, Reprint and Cir. Series, No. 113, 1942; Mitchell and Edman, Ill., Nutr. Abstracts and Reviews 21, 1951–52, pp. 787–804; Schmidt and Rand, Amer. Jour. Vet. Res., 13, 1952, pp. 38–49. See also: Mitchell et al., Ill. Bul. 434; Tolle and Maynard, N.Y. (Cornell) Bul. 530; Neeley and Harbaugh, Tex., Jour. Amer. Vet. Med. Assoc., 124, 1954, pp. 340–350; Stoddard et al., Utah, Jour. Dairy Sci., 38, 1955, p. 626; Halpin and Lamb, Wis., Poultry Sci., 11, 1932, pp. 5–13; Hauck, Steenbock, Lowe, and Halpin, Wis., Poultry Sci., 12, 1933, pp. 242–249; Phillips, Halpin, and Hart, Wis., Jour. Nutr., 10, 1935, pp. 93–98; Udall and Keller, Cornell Vet., 42, 1952, pp. 159–184.
27. Hobbs et al., Tenn. Bul. 235.
28. Phillips, Hart, and Bohstedt, Wis. Res. Bul. 123.
29. Phillips, Greenwood, Hobbs, and Huffman, National Res. Council, Pub. 381, 1955.
30. Hart, Phillips, and Bohstedt, Wis., Amer. Jour. Pub. Health, 24, 1934, pp. 936–940.
31. Welch, Mont. Bul. 214; Mont. Cir. 145; Bell, Ohio Bul. 470; Kalkus, Wash. Bul. 156; Hart and Steenbock, Wis. Bul. 297; Hadley, Wis. Bul. 352.
32. Willman, Asdell, Morrison, and Krider, N.Y. (Cornell) Rpt. 1942.
33. Rodenwold and Simms, Ore., Amer. Soc. Anim. Prod., Proc. 1934; Harvey, Minn., Amer. Soc. Anim. Prod., Proc. 1929.
34. Hamilton and Kick, Ill., Jour. Agr. Res., 41, 1930, pp. 135–137; Evvard and Culbertson, Iowa Res. Bul. 86, Iowa Rpt. 1928; Vinke, Mont., mimeo. rpt; Russell, N.J. Rpt. 1928; Bartlett, N.J. Rpt. 1930; Severson, N.D., information to the author; Krauss and Monroe, Ohio Bul. 470; Forbes et al., Penn., Jour. Agr. Res., 45, 1932, pp. 113–128; Hart, Hadley, and Humphrey, Wis. Res. Bul. 112; Holmes, Pigott, and Packard, Jour. Nutr., 8, 1934, pp. 583–595.
35. Davis, Fla., statement at North Carolina Nutr. Conf., 1951.
36. Boughton and Hardy, Tex. Bul. 499; see also: Davis, Kidder, and Becker, Fla. Bul. 513.
37. Neal and Ahmann, Fla., Jour. Dairy Sci., 20, 1937, pp. 741–753; Becker, Neal, Dix Arnold, and Rusoff, Fla. Rpt. 1939; Becker and Henderson, Fla. Dept. Agr. Bul. 115; Davis, Kidder, and Comar, Fla., Jour. Anim. Sci., 5, 1946, p. 393; Becker, Dix Arnold, Kirk, Davis, and Kidder, Fla. Bul. 513.
38. For detailed discussions of these deficiency diseases see the review by Russell, Imperial Bureau of Anim. Nutr., Great Britain, Tech. Communication 15, 1944; also, see Beeson, U.S. Dept. Agr. Misc. Pub. 369.
39. Becker, Dix Arnold, Kirk, Davis, and Kidder, Fla. Bul. 513; Strong and Committee, Cal. Spec. Cir.; Cunningham, Brown, and Edie, Canadian Jour. Agr. Sci., 33, 1953, pp. 254–260.
40. Jamieson and Allcroft, British Jour. Nutr., 4, 1950, pp. 16–31.
41. For reviews of investigations on cobalt and other trace minerals, see: Russell, Imperial Bureau of Animal Nutrition, Great Britain, Tech. Communication 15, 1944; Underwood, Nutr. Abstr. and Rev. 9, 1940, pp. 515–534; Marston, Psysiol. Reviews, 32, 1952, pp. 66–121; see also: Becker, Dix Arnold, Kirk, Davis, and Kidder, Fla. Bul. 513.
42. Becker, Dix Arnold, Kirk, Davis, and Kidder, Fla. Bul. 513; Dickey, Maine Bul. 491; McIntyre, Duncan, Reid, Huffman, and Killham, Mich., Jour. Anim. Sci., 3, 1944, pp. 438–439; Keener, Percival, and Morrow, N.H. Bul. 411; Smith, Becker, Loosli, and Beeson, N.Y., Jour. Anim. Sci., 9, 1950, pp. 221–230; Geyer, Rupel, Hart, et al., Wis. Bul. 465; Bowstead and Sackville, Canadian Jour. Res., 17, 1939, pp. 15–28; Beeson, U.S.D.A. Agr. Inf. Bul. 7.
43. Keener, Percival, and Morrow, N.H. Bul. 411; Koch and Smith, N.Y., Jour. Anim. Sci., 10, 1951, pp. 1017–1021; Kercher and Smith, N.Y., Jour. Anim. Sci., 14, 1955, pp. 458–464.
44. Keener et al., N.H. and U.S.D.A., Jour. Dairy Sci., 38, 1955, p. 626.
45. Keener, Percival, and Morrow, N.H. Bul. 411; Becker and Smith, N.Y., Jour. Anim. Sci., 10, 1951, pp. 266–271.
46. Whiting, Slen, Bezeau, and Clark, Canada, Jour. Anim. Sci., 12, 1953, p. 936.
47. Jones, Haag, and Weswig, Ore., Jour. Dairy Sci., 35, 1952, p. 503.
48. Ore. Buls. 477, 491.
49. Davis, Williams, and Loosli, N.Y., Jour. Dairy Sci., 37, 1954, pp. 813–818.
50. Hale and Garrigus, Ill., Jour. Anim. Sci., 12, 1953, pp. 492–496; Starks et al., Ill., Jour. Anim. Sci., 13, 1954, pp. 249–257; Thomas,

Loosli, Williams, and Maynard, N.Y., Jour. Nutr., 43, 1951, pp. 515–523; Kulwich, Struglia, Bourne, and Pearson, U.S.D.A., Jour. Anim. Sci., 13, 1954, pp. 989–990.
51. Machlen, Bird, Pearson, and Denton, U.S.D.A., Chem. and Eng. News, Apr. 28, 1952.
52. Sherwood, Couch, James, and Carter, Tex. Bul. 633; McCampbell et al., Kan. Cattlemens' Round-up, 1927.
53. Eaton, Avampato, Curme, and Matterson, Conn. (Storrs) Bul. 295.
54. Miller, Jour. Biol. Chem., 55, 1923, pp. 45–59; 67, 1926, pp. 71–77; 70, 1926, pp. 593–598; Evvard, Brown, Culbertson, and Hammond, Iowa Res. Bul. 94.
55. Huffman, Conley, Lightfoot, and Duncan, Mich., Jour. Nutr., 22, 1941, pp. 609–620; Almquist, Cal., Soc. Exptl. Biol. Med., 49, 1942, pp. 544–545; VanReen and Pearson, Jour. Nutr., 51, 1953, pp. 191–203; see also: Thomas and Okamoto, U.S.D.A., Jour. Dairy Sci., 36, 1953, p. 591.
56. Swanson and Anderson, Kan. Bul. 345; Barrentine, Miss., Jour. Anim. Sci., 7, 1948, pp. 535–536; Miss. Rpt. 65; Daniel et al., Okla., Jour. Anim. Sci., 11, 1952, pp. 790–791; Kunkel, Burns, and Camp, Texas, Jour. Anim. Sci., 12, 1953, pp. 451–458; Sims and Crookshank, Texas and U.S.D.A., Jour. Anim. Sci., 12, 1953, pp. 954–955.
57. Crookshank and Sims, U.S.D.A. and Tex., Jour. Anim. Sci., 14, 1955, pp. 964–969.
58. Berman, Phillips, and Brandly, Wis., Jour. Amer. Vet. Med. Assoc., 121, 1952, pp. 46–50; Gessert et al., Wis., Jour. Dairy Sci., 35, 1952, pp. 693–698; King, Venzke, and Edginton, Ohio, Amer. Jour. Vet. Res., 13, 1952, pp. 152–157; Mo. Buls. 500, 509.
59. Grummer, Bentley, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 9, 1950, pp. 170–175.
60. Outler, Wallace, and Davis, Fla., Jour. Anim. Sci., 14, 1955, p. 1219.
61. Johnson, Ark., Jour. Anim. Sci., 2, 1943, pp. 14–22; 3, 1944, pp. 136–142; Beeson, Briggs, and Andrews, Ind. Rpts. 64, 65.
62. Keith, Miller, Thorp, and McCarty, Penn., Jour. Anim. Sci., 1, 1942, pp. 120–125.
63. Andrews, Lundquist, Urban, and Quackenbush, Ind. Rpt. 66.
64. Stirn, Elvehjem, and Hart, Wis., Jour. Biol. Chem., 109, 1935, pp. 347–359; Wachtel, Hove, Elvehjem, and Hart, Wis., Jour. Biol. Chem., 138, 1941, pp. 361–[illegible].
65. Luecke, Hoefer, and Thorp, Mich., Jour. Anim. Sci., 14, 1955, p. 1215; Lewis, Hoekstra, Grummer, and Phillips, Wis., Jour. Anim. Sci., 14, 1955, pp. 1214–1215; Grummer, Wis., Hoard's Dairyman, July 25, 1955.
66. Heller and Burke, Okla., Jour. Biol. Chem., 74, 1927, pp. 85–93; see also: Graham, Sampson, and Hester, Ill., Jour. Amer. Vet. Med. Assoc., 97, 1940, pp. 41–47.
67. Evvard, Culbertson, et al., Iowa Leaflets 13, 120; Willman and Morrison, N.Y. (Cornell) Bul. 836; Totusek and Beeson, Ind., Jour. Anim. Sci., 12, 1953, pp. 271–281; Grummer, Meyer, and Bohstedt, Wis., Jour. Anim. Sci., 10, 1951, pp. 543–544.
68. Almquist and Zander, Cal., Soc. Exptl. Biol. and Med., 45, 1940, pp. 303–305.
69. Heuser, N.Y. (Cornell) Rpt. 1939; Heuser, Feeding Poultry, 2nd Ed., 1955, p. 128.
70. Perkins, Ohio Bimo. Bul. 159.
71. Wells and Ewing, Ga. Bul. 119; Lamb and Evvard, Iowa Res. Buls. 70, 71; Steenbock, Nelson, and Hart, Wis., Jour. Biol. Chem., 19, 1914, pp. 399–419; Blatherwick, Jour. Biol. Chem., 42, 1920, pp. 517–539.
72. Braude, Jour. Agr. Sci., England, 35, 1945, pp. 163–167.

CHAPTER VII

VITAMINS IN LIVESTOCK FEEDING

I. Importance of Vitamins

188. Modern rations based on vitamin discoveries.—Our present-day efficient rations for livestock, especially for poultry and swine, have largely been made possible because of the rapid succession of discoveries concerning vitamins. These discoveries have not only greatly increased the efficiency of animal production, but also have made possible the prevention of serious nutritional diseases.

For example, before the functions of vitamins were known, pigs that were born in the fall in the northern states often failed to thrive and many became paralyzed or died from pneumonia or other diseases. This fall-pig problem has been solved through the use of improved rations that provide an ample supply of the essential vitamins. Similarly, before the necessity of vitamins in poultry feeding was understood, it was difficult to grow thrifty chicks during the seasons of the year when they could not get out in the sunshine and secure green forage. Now they can be raised efficiently at any season of the year.

In the southern states cattle fed heavily on cottonseed meal often died from what was thought to be "cottonseed meal poisoning." It was discovered that the trouble was due mainly to a vitamin deficiency. As a result, it is now possible to feed dairy cows for long periods on cottonseed meal as the only concentrate without any injurious results whatsoever.

The discoveries concerning the occurrence and functions of vitamins have nearly all been made since 1911. Previous to that time even the existence of vitamins as definite food essentials was unknown. It was then generally believed that the only requirements to make a satisfactory diet for humans or a complete ration for farm animals were adequate supplies of proteins, carbohydrates, fats, and minerals.

Certain investigators had previously reported that laboratory test animals, such as rats or mice, did not thrive on a highly-purified diet made up of the nutrients that were then known. Furthermore, they had found that when certain natural foods, like milk, were added to such a diet the animals would thrive. They therefore concluded that some other substances must be essential for animal life, in addition to the recognized classes of nutrients. It is rather surprising that these interesting observations attracted little attention at the time from other investigators.

In 1912 it was discovered that a mysterious substance (now known as thiamine) was able to prevent or cure the disease called beri-beri in experimental animals. This substance was called "vitamine." The general name of *vitamin* has since been used for the considerable number of mysterious organic substances, discovered later, which are essential for animals but which are needed in only exceedingly small amounts.

Shortly after the discovery of the first vitamin was announced, it was reported that scurvy in experimental guinea pigs could be cured by feeding small amounts of fresh green feeds that supplied the antiscorbutic factor, which we now call ascorbic acid or vitamin C. Then, in 1913 investigators in two different laboratories discovered a food essential in butterfat (now known as vitamin A), which was necessary for growth and even for life itself. Since that time hardly a year has passed without some discovery of major significance in this field.

In addition to the considerable number of vitamins which have been definitely isolated and investigated, experiments with poultry have shown that there are still other unidentified vitamins which are essential, at least for them. (222)

The various vitamins that have been identified are widely different in chemical structure. The vitamins are therefore not related chemically to each other, as as are the proteins, the fats, or the carbohydrates. The functions of the various vitamins are also entirely different. The vitamins are grouped together because each vitamin is organic in nature and because, at least for certain animals, it is a nutritive essential required only in an exceedingly small amount.

A *vitamin* may be defined as an organic nutritive essential which is required in only a very minute amount.

Certain vitamins are apparently needed by but a few species of animals. Others are probably required by all species, but there is no need for a supply in the feed. This is because an ample amount of the vitamin is synthesized, either in the body tissues or by bacteria within the digestive tract. Vitamin A is required by all animals and can be made in the body only from carotene contained in plants. Animals must therefore receive in their food a sufficient supply of vitamin A or of carotene.

Only the briefest summary can be presented here concerning the functions and the occurrence in various feeds of the different vitamins. The special vitamin requirements of each class of stock are discussed in the respective chapters of Part III. For further information concerning the chemistry and functions of the vitamins, the reader is referred to recent texts on biological chemistry and to the books dealing exclusively with this subject.[1]

EXPERIMENTS WITH RATS HAVE SOLVED MANY PROBLEMS

Much of our knowledge concerning proteins, vitamins, and minerals has been gained through experiments with small laboratory animals. Equipment for investigations with rats and other small animals in the Animal Nutrition Laboratory, Animal Husbandry Department, Cornell University. (From McCay and Maynard.)

189. Vitamin content of important feeds.—The information concerning the amounts of the different vitamins in various feeds is exceedingly limited, in comparison with the great numbers of analyses for the ordinary nutrients, and even for calcium and phosphorus. Fur-

thermore, the amounts of a particular vitamin in various lots of a certain kind of feed may vary widely, depending on the quality of the feed, the stage of growth, and in the case of hay or other dry forage, on how it has been cured.

The approximate amounts of carotene (vitamin A value) and of thiamine, riboflavin, niacin, pantothenic acid, and choline in some of the most important feeds are stated in Appendix Table V, so far as data are available. The information concerning the content of the other vitamins is very limited. So far as data are available, the approximate amounts of other vitamins in certain feeds are stated in Appendix Tables Va, Vb, Vc, and Vd.

One of the exceedingly important facts in livestock production is that all green forage crops are rich in most of the vitamins required by farm animals. The only exceptions seem to be vitamin D and vitamin B_{12}. In the case of animals on pasture and thus exposed to sunlight, vitamin D is supplied by the effect of the ultra-violet rays in sunlight. While the green forage plants thus far studied do not seem to have appreciable amounts of vitamin B_{12}, nevertheless poultry on good pasture do not apparently need any vitamin B_{12} supplement, although they have a definite requirement for the vitamin.

Silage and well-cured hay, especially alfalfa and other legume hay, are also good sources of most of the vitamins. Hay and other dry forage cured in the sun even supply considerable vitamin D. When farm animals are not on pasture, plenty of good hay and silage will ordinarily provide ample amounts of vitamins, except in the case of poultry, which need vitamin supplements, as emphasized in Chapter XXXVI.

Green forage crops not only supply most of the vitamins which have been discovered thus far, but they also furnish other unknown vitamins that are needed by livestock. This is shown by the fact that farm animals may suffer from nutritive deficiencies when never allowed on pasture or fed fresh green forage.

For example, it is shown in Chapter XXXIV that brood sows which are kept in dry lot are often unable to reproduce normally, even when fed an apparently well-balanced ration. When pasture or other green feed is supplied, the ration is made complete, and the sows can raise thrifty litters.

Alfalfa or other legume hay of good quality is the best substitute for pasture in furnishing unknown but necessary vitamins. However, even the best of hay is not a perfect substitute for green feed such as pasture. It is therefore important that good pasture be provided for livestock, and especially for breeding animals, during as much of the year as possible.

190. Antivitamins, or antimetabolites.—In certain cases a food may contain a substance that prevents the action of a vitamin or even destroys it. Such a substance is called an *antivitamin,* or antimetabolite, for the vitamin. An example of this action is a paralysis of foxes raised for fur, which is caused by an antivitamin in certain raw fish that destroys the vitamin thiamine. Bracken fern poisoning of cattle also seems to be caused by an antivitamin of thiamine.

II. Vitamin A and Carotene

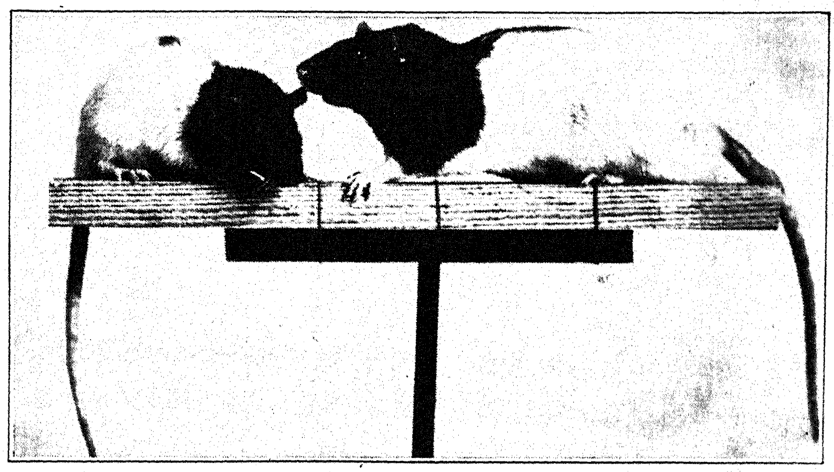
191. Importance of vitamin A.—In livestock feeding, as well as in human nutrition, vitamin A ranks first in importance among the vitamins. It is required by all animals, including poultry, and it is often deficient in practical rations. Unless care is taken to include in the rations fed farm animals a sufficient amount of feeds rich in vitamin A value, the results will be unsatisfactory and disaster may follow.

Vitamin A is essential even for the maintenance of mature animals. For growth, reproduction, and milk production, greater amounts are needed than for mere maintenance.

Vitamin A does not occur as such in feeds of plant origin. However, as is shown later, green-leaved plants and certain other feeds of plant origin contain substances grouped under the term *carotene,* which can be converted into vitamin A within the bodies of animals.

The *vitamin A value* of a feed or a ration means the total vitamin A potency, no matter whether it is supplied by vitamin A or by carotene.

The vitamin A requirements of each class of livestock are considered in detail in the respective chapters of Part III. The amounts of carotene or vitamin A advised for the various farm animals are stated in the Morrison feeding standards. (Appendix Table III.) For all classes of stock except poultry, the requirements are stated in terms of carotene, since these animals usually get their supply of vitamin A in this form. For poultry, the requirements are stated in U.S.P. (United States Pharmacopoeia) units of vitamin A value, which take into consideration both vitamin A and carotene. This is done because in poultry feeding vitamin A value may be supplied both in the form of carotene, as in alfalfa meal or green feeds, and in the form of actual vitamin A, as in fish oils.



VITAMIN A WAS DISCOVERED IN EXPERIMENTS WITH RATS

The thrifty rat on the right received plenty of vitamin A in the form of butterfat. The rat on the left is of the same age, but has been stunted, due to a lack of the vitamin. Also, it is nearly blind. (From Steenbock and Hart, Wisconsin Station.)

192. Functions of vitamin A; effects of deficiency.—One of the chief functions of vitamin A is to keep the mucous membranes of the body healthy, so they will resist infection. A lack of the vitamin is especially apt to cause disease of the respiratory system. For example, calves and pigs fed rations deficient in vitamin A often die from pneumonia. A serious deficiency also injures the nervous system and may cause a staggering gait and finally spasms or paralysis.

One of the first symptoms of vitamin A deficiency is night blindness, or inability to see in dim light. This effect is produced because vitamin A is a part of the substance called visual purple, which is necessary for vision in dim light and which is partly used up through the action of light. Animals which are night blind recover when supplied with an ample amount of vitamin A.

More serious types of blindness are also caused by a lack of vitamin A. Thus, calves suffering from a severe deficiency of the vitamin may become blind, because of constriction of the optic nerves where they pass through the skull.[2] In other types of blindness, the cornea of the eye becomes cloudy and opaque, and the eye membranes are so changed that bacteria invade the eye and cause ulceration.

In calves common symptoms of a deficiency are poor growth, cold in the head with nasal discharge and sometimes

with a cough, and also scours. If the deficiency is continued, the calves usually succumb to pneumonia or other respiratory diseases. In fattening cattle kept for a long time on a ration deficient in vitamin A, a characteristic symptom of deficiency is dropsical swelling of the legs, known as anasarca.[3]

The so-called "cottonseed-meal poisoning" produced when cattle are fed for a long time on such a ration as cottonseed meal and cottonseed hulls, is due primarily to deficiency of vitamin A. (811) It can readily be prevented by feeding hay, silage, or other roughage that supplies sufficient carotene.

In chickens symptoms somewhat resembling roup often develop, with a sticky or cheesy discharge from the eyes and a sticky discharge from the nostrils.

A severe lack of vitamin A prevents successful reproduction. Females fed rations seriously deficient in vitamin A may not conceive, and if they do, the young are usually born dead or so weak that they perish.[4] A long-continued severe deficiency of vitamin A may affect the fertility of male animals and may cause degeneration of the sperm-producing cells. However, other symptoms of vitamin A lack are usually produced in males, before their fertility is impaired.

That disastrous results due to a lack of vitamin A may occur in livestock, even when they are on range pasture, is shown in a striking manner by California investigations.[5] During the dry season in some of the range districts of that and certain other western states, no green feed may be available for several months. The stock must then live on dry and bleached grass and other forage, which has practically no vitamin A value.

Often the cows abort, or the calves are born dead or so weak that they soon die. After calving, the cows may fail to come in heat until green feed is again available. Young cattle also suffer seriously, showing a general unthrifty appearance, intermittent diarrhea, and respiratory infections. If exposed to bad weather, such animals usually die from pneumonia. Unless the animals have been too seriously affected, they recover when supplied with feed rich in vitamin A value, such as fresh green forage or good quality alfalfa hay.

Animals are able to store considerable amounts of vitamin A in their livers and other tissues when they receive a liberal supply. Therefore, the length of time it will take for a lack of the vitamin to produce injurious results will depend on whether or not the animals have a store in their bodies at the start. Because of their greater requirements for vitamin A, young animals suffer from a deficiency much sooner than those which are mature. In Texas studies beef calves 3 to 5 months of age showed symptoms of night blindness in 56 days on the average, when fed a vitamin A deficient ration, while it took about 6 months for the symptoms to develop in yearling steers.[6]

Young mammals are born with only a small store of vitamin A in their bodies, even when their mothers have a liberal supply in their feed. However, colostrum, or the first milk, from well-fed animals is especially rich in vitamin A value. (270) This is one reason why it is so important that new-born mammals receive the colostrum. Investigations with cows, goats, and sows have shown that the vitamin A value of the colostrum milk, and in some cases even the store in the young at birth, can be increased by a very high intake of vitamin A or carotene during the latter part of pregnancy.[7]

193. Vitamin A and carotene.—Experiments have shown that vitamin A, which is nearly colorless, does not occur as such in plant products. However, all green-leaved parts of plants contain certain yellow-colored compounds, classed together as carotene, which animals can convert into vitamin A. Carotene is changed into vitamin A in the wall of the small intestine, and possibly to a small extent in the liver and other tissues.

The chief form of carotene in most green-leaved plants is beta-carotene. Other forms, called alpha-carotene and gamma-carotene, also occur in smaller amounts in plants. The vitamin A value of yellow corn is due chiefly to its content of cryptoxanthine, a closely related

compound. It is of interest that beta-carotene has twice as high a vitamin A value as do the other forms, because two molecules of vitamin A can theoretically be formed from each molecule of beta-carotene. Only one molecule of vitamin A can be made from each molecule of the other compounds. Still other compounds from which vitamin A can be formed have been found in algae and bacteria. These are not of importance in stock feeding.

Not all yellow pigments in plants have a vitamin A value. For example, xanthophyll, which occurs along with cryptoxanthine and carotene in yellow corn, has none.

Those foods of animal origin that possess vitamin A value may contain both the colorless vitamin A and also yellow carotene. In the white milk from Holstein or Ayrshire cows there is more vitamin A and less carotene than in the yellow milk from Guernseys or Jerseys. The difference is due to the fact that Holsteins and Ayrshires convert the carotene from their feed more completely into vitamin A. (**1043**)

The vitamin A value of fish-liver oils and other fish oils is due to vitamin A and not carotene. It is of scientific interest, but not of practical importance, that some of the vitamin A in fresh water fishes differs in structure from ordinary vitamin A. This form is called vitamin A_2, and sometimes the ordinary form is designated as vitamin A_1 to distinguish it from the uncommon form.

194. Vitamin A and carotene requirements.—Because of the importance of vitamin A and carotene for livestock, the requirements of each class of stock are considered in the respective chapters of Part III. The amounts of carotene advised for the various animals, except poultry, are stated in the Morrison feeding standards. (Appendix Table III.) The vitamin A requirements of poultry are stated in Chapter XXXVI.

The amounts of carotene recommended for the various animals in Appendix Table III are stated in terms of milligrams of carotene needed per head daily. (1,000 milligrams equal 1 gram, and about 28,000 milligrams equal 1 ounce, avoirdupois.) Appendix Table V shows the average carotene content of the most important feeds, stated in terms of milligrams per pound of feed and also in U.S.P. units per pound.

The total vitamin A value of a feed or ration is stated in U.S.P. units of vitamin A activity. The new U.S.P. unit is the vitamin A value for rats, used as test animals, of 0.30 microgram of pure vitamin A alcohol, or of 0.60 microgram of pure beta-carotene. The U.S.P. unit is the same as the revised International Unit (I.U.).

The relative value of a microgram of carotene and of vitamin A differs considerably for various animals. For rats 0.6 microgram of carotene is equal in value to 0.3 microgram of vitamin A (1 U.S.P. unit). However, the weight of carotene required by calves is 5 or more times the amount of vitamin A needed.

The carotene or vitamin A content of feeds is commonly determined by colorimetric or spectroscopic methods. The total vitamin A value may be measured also in growth tests with young rats.

195. Carotene and vitamin A readily destroyed.—Both carotene and vitamin A are readily destroyed by oxidation. For this reason a great loss of vitamin A value occurs in the ordinary making of hay from green forage. A considerable loss also takes place when dry roughage or a concentrate mixture containing vitamin A is stored for too long a period.

Hay which is made in good weather by modern methods and which is leafy and green in color will still be rich in carotene, though much lower on the dry basis than the green crop from which it was made. On the other hand, hay that is decidedly bleached or weathered will be low in carotene. If hay heats or molds badly in curing or in storage, practically all of the carotene may be lost.

The rate of loss of carotene in hay during storage depends largely on the temperature. The loss is rather rapid in summer and very slow in cold winter weather. In storage, the carotene may be

lost from hay more rapidly than the green color.

There is much less loss of carotene when a hay crop is made into silage by a suitable method than when it is cured into hay in the ordinary way. The loss is still less when the crop is artificially dried, or dehydrated, because of the rapidity with which the plants are dried. However, even in artificially dried hay, such as dehydrated alfalfa meal, a continual loss occurs during storage at ordinary temperatures, unless some means is used to reduce the loss.

The relative losses of carotene in field-cured hay, dehydrated hay, and hay-crop silage are well shown by extensive Vermont experiments.[8] On the average, field-cured hay made in good weather had 42 per cent as much carotene, on the dry basis, when it was stored in the barn, as there was in the green crops when cut. After storage for 6 months the carotene content was only 11 per cent of the original amount, and after a year only 9 per cent.

Dehydrated hay lost but little carotene in the drying process, and after 6 months of storage it still had 57 per cent of the original content. When the crops were made into silage with the addition of molasses as a preservative, the carotene was also retained well. At the time the silage was fed in winter, it still had about 42 per cent as much carotene as there was in the green crops when ensiled.

The vitamin A value of whole yellow corn is retained fairly well in storage. In Iowa tests yellow shelled corn which had been stored for more than a year had three-fourths as much vitamin A value as corn of the previous year's crop, and corn that was 4 years old had about one-half as much.[9]

Large losses of carotene and vitamin A occur in ordinary concentrate mixtures which are stored under usual conditions for any long period.[10] Except in very hot weather, the loss is not serious during storage for 4 to 6 weeks, but one-half or more of the vitamin A value may be lost in 6 months. The presence of rancid fats greatly increases the loss, and the loss is also more rapid when the mixture contains meat scrap, tankage, dried dairy by-products, or certain mineral supplements.

Methods have been developed for reducing the loss during storage of vitamin A in alfalfa meal and in vitamin A supplements added to feed mixtures. Some producers of alfalfa meal store part of their product in tanks in an atmosphere free of oxygen or under refrigeration, in order to retain the carotene content. This alfalfa meal is then mixed with that from ordinary storage, so that a definite carotene content can be guaranteed at any time of the year.

The loss of carotene in alfalfa meal or of carotene and vitamin A in a feed mixture can also be reduced by the addition of a suitable antioxidant.[11] Methods have been devised for stabilizing the vitamin A value of special vitamin A supplements by coating the particles with gelatin or wax, or by adding an antioxidant.

196. Carotene content of roughages.—The approximate amounts of carotene in various roughages and other feeds are given in Appendix Table V. One of the most important facts in stock feeding is that all green parts of growing plants are rich in carotene and hence have a high vitamin A value. Stock on good pasture therefore always have plenty of the vitamin. In green plants the yellow color of the carotene is masked by the green color of the chlorophyll.

The green leaves of plants contain much more carotene than the stems. For example, alfalfa leaves may contain 4 to 6 times as much as the alfalfa stems.[12] For this reason alfalfa leaf meal is higher in carotene than alfalfa meal made from the entire hay. Alfalfa stem meal is relatively low in carotene.

Forage plants generally have the most carotene, on the dry basis, at early stages of growth, and the amount decreases as the forage becomes older. Therefore the content is much lower at the hay stage of growth than at early pasture stages. When plants mature, the carotene decreases greatly, and but little

is left when they become dry and weathered.

While actively growing plants are always rich in carotene, mature, weathered pasture forage may have so little that animals kept too long on such feed alone may suffer severely from vitamin A deficiency. If parts of the plants remain green, these parts will retain some carotene. It was found in New Mexico studies, for example, that black grama grass kept some carotene content during the dry season much better than other range grasses, because the lower parts of the stems remained green.[13]

Investigations have shown that at an immature pasture stage some of the grasses are fully as rich as alfalfa or other legumes in carotene, on the dry basis.[14] Dehydrated grass made from young plants may be as rich in carotene as dehydrated alfalfa.[15]

The relative amount of carotene in any particular lot of hay can usually be estimated roughly from its color and its leafiness. The Federal Hay Grades are therefore generally good indications of the vitamin A value of various lots of hay. However, on long storage the carotene content may be mostly lost, while the hay still is green.

In Michigan studies the carotene content was determined in many samples of legume and mixed hay taken from farmers' barns during the winter feeding season.[16] The average carotene content of the samples of hay that graded U.S. No. 1 was more than twice as high as that of the samples which graded U.S. No. 3.

Legume hay usually has decidedly more carotene than grass hay of equal quality, due in part to the greater proportion of leaves. Soybean hay is generally lower than alfalfa hay in carotene. Straw of all kinds has but little carotene.

Dehydrated or sun-cured alfalfa meal is the most common carotene supplement in poultry rations and is also widely used for other animals when additional vitamin A is needed. (417) Unfortunately, the carotene content of alfalfa meal, even dehydrated alfalfa meal, varies greatly on our markets. This is shown by the analyses reported by the feed inspection services in various states. Some alfalfa meal has had no more carotene than fair hay.

In buying alfalfa meal, it is therefore important to purchase a product that has a carotene content guaranteed by the manufacturer.

Corn forage is rich in carotene when the plants are still green, but the content decreases rapidly as they mature. The carotene value of corn silage varies widely, because of difference in maturity and in extent of loss in the ensiling process. Per pound of dry matter, good corn silage, made from corn harvested before the lower leaves have turned brown, may be as rich in carotene as well-cured hay.

Sorghum silage tends to be lower than corn silage in carotene. This is partly because in this country corn silage is usually made from yellow varieties of corn, and yellow corn grain has considerable carotene value. Sweet sorghum silage generally has more carotene than silage from grain sorghum, probably because it has a greater proportion of leaves.[17]

Silage made from alfalfa or other hay crops is especially high in carotene, on the dry basis, if it is well preserved. (437) Per pound of dry matter, it usually has much more carotene than first-rate hay.

197. Carotene or vitamin A content of concentrates.—With the single exception of yellow corn, the cereal grains have practically no carotene. Yellow corn is an important source of carotene, though it usually contains only one-tenth to one-quarter as much as good legume hay.

The vitamin A value of yellow corn is due to its content of both beta-carotene and the closely-related cryptoxanthine. Xanthophyll, which forms a considerable part of the coloring matter in yellow corn, has no vitamin A value. In general, the deeper the yellow of corn grain, the greater will be the vitamin A value, though there are some exceptions. Corn gluten feed, corn gluten meal, and

hominy feed made from yellow corn are somewhat higher than the whole grain in carotene.

Ripe peas of green varieties equal yellow corn in carotene content, but mature soybean or cowpea seed has but little carotene. Millet seed supplies some carotene.

With the exception of carrots and yellow sweet potatoes, roots and tubers probably supply no appreciable amounts of carotene. In carrots and sweet potatoes carotene is highest in the varieties having the deepest yellow color. Yellow pumpkins and yellow-fleshed squash have considerable carotene.

Among human foods whole milk, butter, and all other dairy products containing the butterfat are perhaps the most important sources of vitamin A. In raising dairy calves on milk substitutes, it is necessary to continue the feeding of whole milk until the calf is old enough to eat considerable hay, or else to include a vitamin A supplement in the milk substitute.

If cows or other lactating animals have been fed for a considerable time on rations deficient in vitamin A value, the content in the milk will be low. The effect of the ration upon the vitamin value of milk and butter is discussed in detail in Chapter XXV, and also the effect of the breed of cow on the vitamin A value and the color of milk and butter. (1043–1044)

Practically all the vitamin A value in milk is present in the butterfat. Therefore skimmilk and other milk products from which nearly all of the fat has been removed will have but little of the vitamin. Indeed, skimmilk may contain only one twenty-fifth as much vitamin A value as whole milk.[18]

LACK OF VITAMIN A DISASTROUS TO PIGS

Above: Pigs fed white corn and skimmilk with alfalfa hay to furnish vitamin A value. All made good gains and remained thrifty.

Below: Pigs fed white corn and skimmilk without vitamin A supplement. Four of the pigs had already succumbed because of the lack of vitamin A. Those which had a greater store of the vitamin at the start survived, but they made unsatisfactory gains. (From Wisconsin Station.)

The yolks of eggs from properly fed poultry are rich in vitamin A, and liver is also an excellent source. Tankage and meat scrap supply little or no vitamin A. If fish meal has not been processed at too high a temperature, it will usually supply some vitamin A. However, the content is so variable that reliance cannot be placed upon it as a source of the vitamin, unless the source and method of manufacture are definitely known. Cod-liver oil and other fish-liver oils are

the richest natural source of vitamin A, and other fish oils are also generally rich in it. The amount of vitamin A in the liver oils from sharks, swordfish, tuna, and certain other species is many times as great as in cod-liver oil.

198. Meeting the vitamin A needs.—In the discussions on vitamin A for the various kinds of animals in Part III, it is shown that it is not generally necessary to use any special vitamin A supplement for dairy cows, beef cattle or sheep, or horses. Their vitamin A needs can be fully met by the use of good roughages, fed as there advised.

On the other hand, poultry not on excellent pasture need additional vitamin A. This is supplied by including alfalfa meal in the mash to furnish carotene, or by adding a vitamin A supplement. Also, for swine not on pasture it is important to include in the ration good quality sun-cured legume hay to provide both vitamins A and D, or else to use a special A-D supplement. Likewise, a vitamin A supplement should be included in a milk substitute for dairy calves weaned from milk at a very early age.

In addition to alfalfa meal, which has been discussed previously, various concentrated vitamin A supplements are produced commercially. Concentrates supplying both vitamin A and vitamin D are made from cod-liver oil and certain other fish oils. In addition, carotene concentrates are produced from dehydrated alfalfa or vegetable wastes, and synthetic vitamin A is made on a large scale. The vitamin potency of these products is guaranteed by the manufacturer.

III. Vitamin D

199. Vitamin D, its functions and importance.—It has been shown in the previous chapter that an adequate supply of vitamin D is necessary for the proper assimilation and use of calcium and phosphorus and the development of good bones and teeth. This vitamin is just as necessary as are ample amounts and proper proportions of these two minerals. Since vitamin D is necessary for the prevention of rickets in young animals, it is often called the anti-rachitic vitamin. Vitamin D is soluble in fat and is therefore one of the fat-soluble vitamins.

The requirements for vitamin D are especially great during growth, when the skeleton is being developed. For mere maintenance, mature animals need much less vitamin D, but more is required during pregnancy and for milk production.

Animals need more vitamin D than normal when there is insufficient calcium or phosphorus in the ration, or when the proportion between the amounts of these minerals is not the most suitable.

The requirements for vitamin D by different species of animals differ widely. Poultry require more vitamin D in their rations than do other farm stock, and the requirement is especially high for egg production. Turkeys need even more vitamin D than do chickens. At the other extreme are foxes and minks, which apparently need no vitamin D when there are optimum amounts of calcium and phosphorus in their diet and also an optimum calcium-phosphorus ratio. White pigs, at least of certain breeds, seem to need very little vitamin D under similar conditions, even when exposed to no direct sunlight.

Animals are able to store some vitamin D in their bodies, chiefly in the liver, when they receive more than their minimum needs, but such storage is relatively small in comparison with the storage of vitamin A. In South Dakota experiments mature dairy cows did not usually show definite symptoms of vitamin D deficiency until after 4 to 10 months, when they were fed a ration devoid of the vitamin and were allowed no exposure to sunlight.[19] Young animals show a lack of vitamin D much sooner. For example, new-born lambs are protected against a deficiency by the store in their bodies for only about 6 weeks.

The requirements of each class of stock for vitamin D are considered in detail in the respective chapters of Part III. It is there shown that generally

there is no need of supplying farm animals with special vitamin D concentrates, except in the case of poultry, and also under certain conditions, dairy calves and swine.

Fortunately, as is shown later in this chapter, sunlight is an effective source of vitamin D for animals, and hay and other dry roughages cured in the sun supply considerable amounts. These sources usually provide adequately for the needs of dairy cows, beef cattle, sheep, and horses. In the colder climates, where swine are not outdoors much in winter, sun-cured legume hay of good quality should be provided if possible, as insurance against lacks of vitamin D or vitamin A. When this cannot be done, a special vitamin A-D supplement should be fed. Vitamin D supplements are commonly needed for poultry, except when they are exposed to plenty of direct sunlight.

If dairy calves are supplied good sun-cured legume or mixed hay as soon as they will eat it, they will usually have sufficient vitamin D. However, as insurance against any possible deficiency, many feed manufacturers include a vitamin D supplement in their calf starters.

In recent Ohio experiments, summarized in Chapter XXVI, cases of milk fever in dairy cows have been lessened by feeding very large doses of vitamin D supplement for a week before calving. (1086) Such large doses cannot be given an animal for any long period without injury.

Vitamin D was discovered in 1922 by McCollum of Johns Hopkins University, who found by passing heated air through cod-liver oil to destroy vitamin A, that it contained a second vitamin which prevented and cured rickets. This was named vitamin D.

The discoveries concerning the functions and sources of vitamin D since that time have been of great value to humans and also to the livestock industry. By using the information now available, stockmen can readily prevent the disastrous results from rickets that were once common, especially in poultry, pigs, and dairy calves.

200. Effects of deficiency of vitamin D.—A serious deficiency of vitamin D in young animals causes rickets, the symptoms of which have been described in the previous chapter. (153) A lack that is not severe enough to cause visible symptoms of rickets may retard growth and result in a weak skeleton, impaired joints, and poor teeth.

Pregnant animals suffering from a severe deficiency of vitamin D will not only produce young which are weak and are subject to rickets, but sometimes the young are born with malformations. Also, the skeleton of the mother is injured by the deficiency.

In mature fowls a deficiency of the vitamin causes thin-shelled eggs, decreased egg production, and lowered hatchability. The breast bone may become soft and rubbery, and the bones of the wings and legs fragile and easily broken.

201. Nature of vitamin D and its relation to light.—Vitamin D is formed by the action of sunlight or other light that contains ultra-violet rays upon a compound called ergosterol and also upon certain other sterols, which are similar compounds. Small amounts of ergosterol occur in most common foods and stock feeds, and traces of the other sterols which can be changed into vitamin D are present in animal tissues. These sterols have no vitamin D effect before they are changed into vitamin D.

The fact that ultra-violet light produces vitamin D in foods was discovered nearly simultaneously by Steenbock of the University of Wisconsin and Hess of Columbia University.

When green forages are field-cured into hay or dry fodder, vitamin D is formed from ergosterol through the action of the ultra-violet light in sunlight. The green, growing parts of plants contain ergosterol, but little or no vitamin D.

Vitamin D is similarly produced when foods are artificially exposed to ultra-violet light. Irradiation for too long a time will destroy some of the vitamin D that has been produced. As yeast contains considerable ergosterol, irradiated

dry yeast, which is extremely rich in vitamin D, is produced commercially by the irradiation of yeast with ultra-violet light.

Sunlight is an effective source of vitamin D for animals, because the ultra-violet light in the sun's rays converts the small amounts of sterols in the skin and the skin secretions into vitamin D. Even the vitamin formed in the skin secretions, outside the skin itself, can be absorbed into the body. Some of the vitamin formed on the skin is also taken into the body when animals lick themselves.

The ultra-violet rays in sunlight are absorbed to some extent as they pass through the atmosphere, before reaching the earth. Therefore the greater the distance that the sun's rays have to travel through the earth's atmosphere, the less is the content of ultra-violet light and the anti-rachitic effect. Sunlight is thus more potent in the tropics and at high altitudes in mountains. Also, the anti-rachitic effect is much greater at noon than early or late in the day, when the rays are very slanting. Similarly, in the temperate zones it is much greater in the summer than in winter. The ultra-violet rays are largely screened out by clouds or smoke. The anti-rachitic effect is hence less in regions where there is a great amount of cloudy weather, or where the air is commonly very smoky.

If sunlight passes through ordinary window glass, practically all the ultra-violet rays are removed. Such light does not therefore have an anti-rachitic effect. Some special kinds of glass and also certain glass substitutes permit the passage of more or less of the ultra-violet rays.

During the growing season stock that are out in the sunshine much of the time generally get ample vitamin D through the effect of sunlight on their bodies. Even in winter, exposure to sunlight has considerable anti-rachitic effect. For example, in Minnesota experiments pigs suffering from rickets caused by a lack of vitamin D recovered to a marked degree when exposed to sunlight in winter for only 45 to 90 minutes a day.[20]

When stock are exposed but little to sunlight that has not passed through ordinary window glass, it is necessary to give attention to their vitamin D requirements. However, it is not necessary for the animal to be in direct sunlight to receive some ultra-violet rays. Owing to the reflection of the ultra-violet light, the indirect light from "sky shine" on a clear day has considerable anti-rachitic effect.

Animals with black or dark hair or skin secure less vitamin D from sunlight than do animals with white or light-colored hair. This is because more of the ultra-violet rays are absorbed by the hair or skin before they penetrate into the tissues. For this reason, white pigs are less subject to rickets than black or dark pigs, when kept under similar conditions.

Although livestock on pasture are usually protected from rickets by the ultra-violet rays in sunlight, rickets in lambs on pasture sometimes occurs in New Zealand for some unknown reason.[21] The trouble can be prevented by administering vitamin D.

202. Relative value of different forms of vitamin D.—Two forms of vitamin D are important. The first is vitamin D_2, which is the form produced by the action of ultra-violet light upon ergosterol, the plant sterol. The other is vitamin D_3, which is produced by the effect of ultra-violet light upon a sterol (called 7-dehydrocholesterol) that occurs in small amounts along with cholesterol in animal tissues. (14) There are also other forms of vitamin D that are not important.

Vitamin D_3, also called activated animal sterol, and sold under the name of Delsterol, is made commercially from animal sterols, by irradiation with ultra-violet light. Vitamin D_3 is believed to be the chief form of vitamin D occurring naturally in cod-liver oil and most other fish oils.

A certain amount of vitamin D potency can be produced by treating certain sterols chemically, but such chemical methods of making vitamin D supplements have not yet been developed commercially.[22]

Vitamin D_2 and vitamin D_3 have approximately the same value for all four-footed animals and also for human beings. Rats are therefore used as test animals to determine the potency of any product in vitamin D for such animals. (No accurate chemical method for measuring vitamin D has yet been developed.)

Vitamin D_2, which is the form in irradiated yeast and in sun-cured forage, is much less effective for poultry than it is for four-footed animals or for human beings. Indeed, it may take 40 times as much, or even more, of vitamin D_2 to protect chicks against rickets as it does of vitamin D_3. The value of various products as sources of vitamin D for poultry is therefore found in tests with chicks.

Vitamin D potency is measured in terms of International Units (I.U.) of the vitamin. In the recently revised international standard, one I.U. of vitamin D is equal in potency to 0.025 microgram of pure crystalline vitamin D_3. For poultry, the vitamin D requirements and vitamin D values of feeds are expressed as International Chick Units (I.C.U.) to differentiate between vitamin D_3 and vitamin D_2 value.

The new unit, which is equally potent for chicks and other animals, replaces the two standards formerly used—the A.O.A.C. chick unit, based on vitamin D_3 potency, and the old I.U., based on vitamin D_2, for other kinds of stock.

203. Stability of vitamin D.—Both common forms of vitamin D (D_2 and D_3) are much more stable than vitamin A or carotene. They are not readily destroyed, even by heating in the air at a temperature much above the boiling point of water. When vitamin D supplements are mixed with the usual kinds of poultry mashes or other concentrate mixtures, the vitamin D potency is usually retained well during storage for some months, even in summer. The vitamin D value of sun-cured hay or other forage is also retained well on storage.

However, rather rapid loss of vitamin D value may occur if a vitamin D supplement is combined with minerals, especially calcium carbonate, or with dried milk products, as a premix to be added later to a poultry mash or other concentrate mixture. The potency of some dry vitamin D supplements is also apparently lost rather rapidly on storage.

204. Vitamin D content of feeds.—Among the common livestock feeds the only important sources of vitamin D are hay and other roughages that have been sun-cured, or that have had some exposure to sunlight, as in making barn-dried hay or wilted grass silage. The vitamin D in field-cured roughages is vitamin D_2, and therefore has a very low value for poultry.

There is as yet relatively little information available concerning the amounts of vitamin D in the various kinds and grades of hay and other dry forages, because of the difficulty and expense in making vitamin D determinations. The approximate vitamin D content in various feeds is stated in Appendix Table Vc, so far as data are available.

The data thus far published show that the amount of vitamin D, even in sun-cured hay, varies widely.[23] However, in a New York study samples of various kinds of hay, taken from farmers' barns during the winter feeding season, all had 450 I.U. or more of vitamin D per pound, the average for 14 lots of hay being 854 I.U. per pound.[24] Only 3 lbs. of hay containing 500 I.U. per pound will meet the vitamin D needs of a 500-lb. calf, which is housed in a stable where it has no exposure to sunlight.

Differing from the carotene content, the amount of vitamin D may be as high in hay that is of lower quality, because of injury from bad weather during curing, as in first-quality hay that is very green in color.

In field-cured hay, the leaves have much more vitamin D than do the stems. Probably leafy hay is usually higher in vitamin D than stemmy hay. However, a high content of 748 I.U. per pound has been reported for wheat straw.

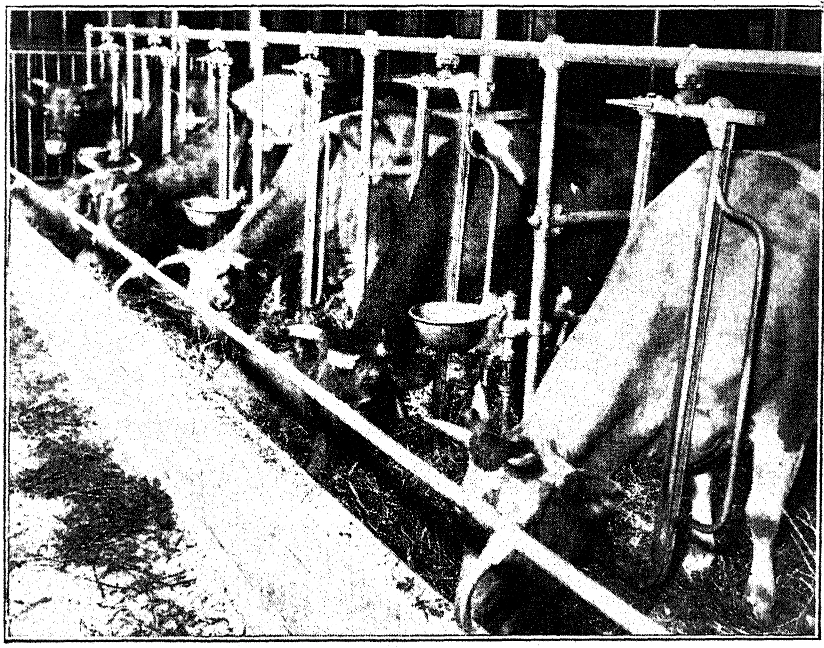
Information is insufficient to draw definite conclusions about the relative vitamin D content of various kinds of

field-cured hay, but grass hay seems to be somewhat lower, as a rule, than legume hay.

It has been generally believed that the green, growing parts of plants have little or no vitamin D, and that it is formed only during the sun-curing process by the action of the ultra-violet rays. However, leaves or stems that had died or were brown have been found to have considerable vitamin D.

content varies so widely that it cannot be relied on as a source of this vitamin. As has been stated previously, dehydrated hay is used primarily as a carotene supplement.

In experiments by the United States Department of Agriculture, wilted alfalfa silage or barn-dried alfalfa hay, fed at the usual rates, had plenty of vitamin D to prevent any symptoms of rickets in dairy calves housed in the dark



FIELD-CURED HAY FURNISHES VITAMIN D

Hay cured in the sun is an effective source of vitamin D for all livestock except poultry. Other field-cured roughage, such as corn fodder or straw, also supplies considerable vitamin D.

In a recent Vermont experiment it was found that green leaves which were hand-picked from hay plants and then cured in a dark barn away from sunlight, nevertheless had considerable vitamin D.[25] Also, in other trials some dehydrated alfalfa hay has had so much vitamin D that rickets could not be produced in dairy calves fed the hay and kept away from all sunlight.[26] Though dehydrated hay may sometimes have an appreciable amount of vitamin D, the

away from the sunlight, even though the calves had first been depleted of the vitamin before the experiment began.[27] Similar results were secured in Vermont trials with barn-dried hay.[28]

Corn silage ensiled at the dent stage, when the lower leaves had become dry, contained 40 International Units per pound on the average in Michigan studies.[29] The vitamin D content was almost entirely in the dried parts—the lower leaves and the tassels, husks,

and silk—for the green leaves had practically none.

An important fact in stock feeding and also in human nutrition is that none of the cereal grains or other common seeds contains any appreciable amount of vitamin D. Indeed, cocoa shells are the only seed by-product that has been found to have any significant amount of the vitamin. It is apparently formed in cocoa shells through the exposure of the cocoa beans to the tropical sunlight in the curing process.

The livers of fish are strikingly rich in vitamin D, and also the body oils of most fish contain considerable amounts. For this reason cod-liver oil and certain other fish oils are used as vitamin D supplements for infants and for poultry or other animals. Clams and oysters contain some vitamin D.

Fish meal is variable in vitamin D content, some fish meals being a fair source and others containing but little. The content depends on the source of the raw material and on the degree of heat used in the process of manufacture.

Meat scrap and tankage supply no appreciable amounts of vitamin D. In general, meat from mammals contains practically none of the vitamin, except from such organs as the liver and kidneys, which may have limited amounts. In contrast, the yolks of eggs from poultry receiving ample vitamin D are rich in the vitamin.

205. Vitamin D supplements.—Because of the richness in vitamin D as well as vitamin A, cod-liver oil and certain other fish-liver oils and fish-body oils are used as vitamin D supplements. The vitamin content is commonly guaranteed by the manufacturer. At present concentrated vitamin D supplements are in more general use.

By removing the true fat or oil (which contains no vitamins) from cod-liver oil or other fish oils, vitamin concentrates are prepared which are much more potent than the original fish oils. These supply both vitamin A and vitamin D (vitamin D_3) and are commonly sold with definite guarantees of vitamin value.

Irradiated yeast, produced by treating yeast with ultra-violet light, is an effective vitamin D supplement for humans and for four-footed animals. As has been previously stated, it has a low potency for poultry. Various types of irradiated yeast are made with guaranteed potencies ranging from 4,000,000 to 64,000,000 International Units of vitamin D_2 per pound.

In the production of the product known as viosterol, or calciferol, the ergosterol is separated from yeast and then irradiated. This gives a product still more potent in vitamin D_2 on the dry basis.

Activated animal sterol, or irradiated cholesterol, which supplies vitamin D_3, is used extensively as a vitamin D supplement for poultry. The vitamin potency is guaranteed in terms of International Chick Units (I.C.U.) of vitamin D, and a common guarantee is 900,000 units per pound.

206. Vitamin D in milk; vitamin D milk.—Whole milk from cows fed normal rations contains a significant, though relatively small, amount of vitamin D, and milk and butterfat are of considerable importance as sources of the vitamin for man. The vitamin D content of normal milk ranges from 3 to 56 International Units per quart. Summer milk usually has considerably more than winter milk, because of the exposure of the cows to sunlight. Skimmilk and other dairy products containing but little butterfat have only traces of the vitamin.

There is apparently little difference in the vitamin D content of the butterfat in the milk of the various breeds of cows. Because Guernsey and Jersey milk is rich in fat, it supplies somewhat more of the vitamin than milk lower in fat. If cows are fed a ration low in vitamin D and are not exposed to sunlight, their milk will be lower than normal in the vitamin.

Even summer milk does not supply enough vitamin D to protect infants fully against rickets, if they receive no other source of the vitamin. Therefore vitamin D milk, usually containing not less than 400 International Units of the vitamin

per quart, is produced commercially. The most common method now is to add a vitamin D concentrate to the milk. The vitamin D content of milk can also be increased by irradiating the cows with ultra-violet light, or by feeding them irradiated yeast. When cows are fed irradiated yeast, a very high intake is needed to raise the vitamin D content of the milk to the desired level.

It is pointed out in Chapter XXV that when cows are fed ordinary good rations and have the normal amount of exposure to sunlight, they are not benefited by feeding them a vitamin D supplement. (**1046**)

207. Effect of cod-liver oil on herbivora.—Cod-liver oil has been widely used as a satisfactory vitamin supplement for humans and for poultry. However, when cod-liver oil is given to herbivora for long periods, injurious results may be produced. For example, in New York experiments fatal results were produced when sheep, goats, rabbits, or guinea pigs were fed cod-liver oil for a long time, even though the amounts of cod-liver oil were not excessive.[30] In these animals there was a degeneration, or dystrophy, of various muscles, including the heart, in some cases. Similar injurious results to calves and other animals have also been reported by other investigators. The bad results may have been due to destruction of vitamin E caused by the cod-liver oil. When fed to cows or goats, cod-liver oil and certain other fish oils also cause a marked decrease in the fat content of the milk. (**1064**)

Because of these results it does not seem wise to use cod-liver oil over long periods as a vitamin supplement for herbivora (including cattle, sheep, goats, and possibly horses). In the cases where it is advisable to add a vitamin supplement to rations made up of ordinary feeds for these classes of stock, it is apparently safer to use a vitamin concentrate instead.

IV. The B-Complex Vitamins

208. Vitamin B complex.—In the regions of the Orient where polished rice is the chief food of the people, the disease known as beri-beri was widespread until it was found that this disease was due to vitamin deficiency. The symptoms of the disease are loss of appetite, fatigue, depression, and other nervous disorders.

It was at first believed that beriberi was caused by the lack of a single vitamin, which was called vitamin B. It was found later that what was formerly thought to be one vitamin actually consists of separate vitamins that have different functions. The term "vitamin B complex" is now used for the group of vitamins included in what was formerly considered to be the single factor, vitamin B. All the vitamins in the vitamin B complex are soluble in water.

At least 10 B-complex vitamins have been discovered thus far, and there is some evidence that others exist. Some of these vitamins are widely distributed in ordinary livestock feeds, and therefore there is no lack of them in practical rations. Deficiencies occur only when farm animals are fed rations made up of purified nutrients under experimental conditions.

Fortunately, the various B-complex vitamins are synthesized by the bacteria in the rumen of ruminants.[31] An ample supply thus becomes available to the ruminant, even when there might be a lack in the feed itself. Deficiencies of these vitamins are therefore not apt to occur in the case of cattle, sheep, or goats, at least after the animals have reached an age when the rumen has become well developed. Occasionally, there may be a deficiency, if normal bacterial action does not take place in the rumen, because the animal is suffering from other nutritive lacks or is otherwise in poor health.

Considerable synthesis of B-complex vitamins occurs in the caecum and large intestine of the horse,[32] and a limited amount may also take place in the intestines of other animals. This may appreciably reduce the supply needed in the feed.

209. B-complex vitamins in livestock feeding.—Green forages have a

good supply of all of the B-complex vitamins, except vitamin B_{12}. It is surprising that although laboratory determinations have not shown any appreciable amounts of this vitamin in green, growing forage, nevertheless growing chickens on good pasture never seem to have a deficiency of the vitamin, although they definitely need it in their diet. Well-cured hay and good silage are undoubtedly good sources of most of the B-complex vitamins.

The amounts of the B-complex vitamins in important feeds are stated in Appendix Tables V, Va, and Vb, so far as data are available.

When dairy cows, beef cattle, or sheep receive ordinary rations that include satisfactory roughage, no attention need generally be given to the B-complex vitamins, because of the synthesis of these vitamins in the rumen. (44) A deficiency of B-complex vitamins can be produced in very young calves or lambs by feeding them highly purified diets containing no hay or even grain. However, when dairy calves are raised by the usual methods on natural feeds, there is generally no benefit from the use of vitamin pills or capsules to supply additional B-complex vitamins. (1120) Under natural conditions beef calves and lambs are well supplied with these vitamins.

Swine need the B-complex vitamins in their feed, because there is but little synthesis of them in their digestive tracts. Nevertheless, their requirements can be met if they are provided during the growing season with good pasture and if sufficient well-cured legume hay is included in their rations when they are not on pasture. However, for pigs not on pasture there may be an appreciable benefit from adding a B-complex vitamin supplement to the ration, especially a vitamin B_{12} supplement. Such additions to swine rations are discussed in Chapter XXXIV.

Poultry have such high requirements for riboflavin that it is necessary to include a riboflavin supplement in most rations, unless the birds are on good pasture. Some practical poultry rations are also deficient in vitamin B_{12} and certain other B-complex vitamins. The requirements of poultry for the B-complex vitamins and the use of supplements supplying them are therefore discussed in detail in Chapter XXXVI.

It has been reported that periodic ophthalmia, a perplexing disease that sometimes occurs in horses, may be prevented but not cured by a riboflavin supplement.

210. Yeast as a B-complex supplement.—Various forms of yeast, especially brewers' dried yeast, are sometimes used as a B-complex vitamin supplement for livestock. There is no advantage in adding yeast to usual well-balanced rations for dairy cows, dairy heifers, beef cattle, sheep, or horses, because they need no additional supplies of the B-complex vitamins.

There may be some benefit from including yeast in a calf starter for dairy calves raised on a minimum amount of milk, or in a milk substitute or replacer. (1119)

It does not usually pay to add yeast to rations for swine on pasture or even for those in dry lot which are fed good rations that include legume hay and a protein supplement of animal origin. For pigs in dry lot fed such a ration as grain, soybean oil meal, minerals, and a small percentage of alfalfa meal, there may be a benefit from including yeast, unless the ration has some other B-complex vitamin supplement.

Brewers' dried yeast furnishes some of the thus far unidentified vitamins needed by poultry. As shown in Chapter XXXVI, there is an advantage in adding yeast to certain rations for chicks and broilers, if sufficient amounts of these unknown vitamins are not supplied by the other feeds.

211. Thiamine.—Thiamine, which is also called vitamin B_1, prevents the polyneuritis (nervous symptoms) in beriberi and was therefore termed the antineuritic vitamin. A lack of thiamine also causes loss of appetite, failure to grow, emaciation, general weakness, and finally death. Thiamine is an essential part of an enzyme needed for the metabolism

of carbohydrates in the body, and is apparently required by all species of animals.

Thiamine is widely distributed in natural human foods and stock feeds. The unmilled cereal grains are all rich in it, nearly all the thiamine being in and adjacent to the germ and in the aleurone layer. Therefore white flour and polished rice have little. Fresh green forage contains a fair supply of thiamine, as do well-cured hay and other dry forage of good quality. It is supplied in fair amounts by milk and whey. Yeast is especially rich in it. Pure thiamine is produced commercially in considerable amounts by chemical synthesis for use chiefly as a vitamin supplement for humans.

The amounts of thiamine in important feeds, expressed in milligrams of thiamine per pound, are given in Appendix Table V, so far as data are available.

Thiamine is stable in ordinary dry feeds. For example, whole rice stored in an arid climate for 100 years was still rich in it. It is destroyed in neutral or alkaline solution by prolonged boiling.

It is of interest to note that when certain kinds of raw fish are included in the diet of foxes and minks, the thiamine is destroyed so completely that a form of paralysis is produced.

Because of the wide distribution of thiamine in common livestock feeds, farm animals undoubtedly secure ample amounts when fed any usual ration that would be otherwise satisfactory. Also, as has been stated previously, cattle and sheep are not dependent on a supply in their feed, because thiamine is synthesized by bacteria in the rumen.

The thiamine requirements of swine and poultry are stated in Chapters XXXIV and XXXVI.

Young Chick Paralyzed By Lack of Thiamine

This chick was fed an experimental ration lacking thiamine and is suffering from severe polyneuritis. (From Norris and Heuser, Cornell University.)

212. Riboflavin.—Riboflavin, which is also called vitamin B_2 and formerly vitamin G, was the second of the B-complex vitamins to be identified. Riboflavin is of much practical importance for poultry, which have high requirements for it. Their needs for riboflavin and the use of riboflavin supplements are discussed in detail in Chapter XXXVI.

Ruminants commonly have plenty of riboflavin in their usual rations. Also, it is fortunately synthesized in adequate amounts in the rumen, except for a few weeks after birth.

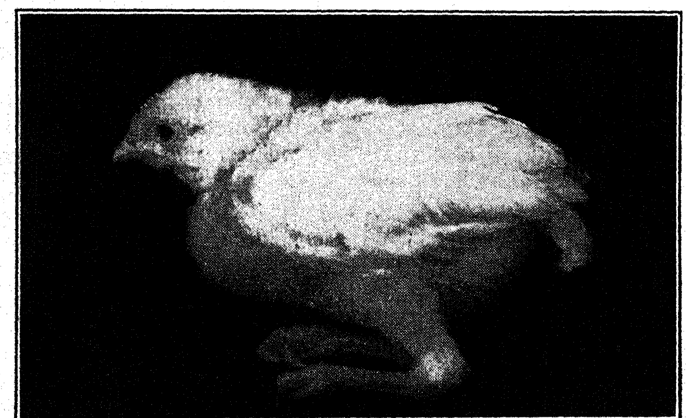
Swine on good pasture receive ample riboflavin, but the experiments summarized in Chapter XXXIV show that there is a benefit from adding a ribo-

flavin supplement to some well-balanced rations for pigs in dry lot.

Riboflavin is an essential part of an enzyme necessary in the oxidation processes of living cells and is therefore probably needed by all living cells. It is also a part of other important enzymes in the body. Riboflavin is essential for the growth of animals and for proper nutrition at all ages. A deficiency is apt to cause digestive disturbances, general weakness, poor condition of the eyes and skin, and nervous symptoms, as well as lessening the resistance to disease.

rich in riboflavin and liberal amounts are furnished by green forages, well-cured hay, and distillery by-products that include the distillers solubles. Whole grains and other seeds have significant amounts of riboflavin, but not enough to provide the chief source for poultry. Wheat bran and middlings supply considerably more riboflavin than does the entire wheat grain. The oil meals and also meat scrap, tankage, and fish meals have fair amounts.

Riboflavin supplements of three types are produced commercially. Syn-



RIBOFLAVIN DEFICIENCY IN A CHICK

Note the characteristic curled-toe paralysis. (From Poultry Husbandry Department, Cornell University.)

In chicks a deficiency of riboflavin causes a characteristic paralysis of the legs, called curled-toe paralysis. In hens a deficiency results in poor hatchability of eggs. A lack of the vitamin in pigs produces slow growth, stiffened legs, chronic diarrhea, skin eruptions, and eye troubles. Experiments, mentioned in Chapter XXXII, indicate that periodic ophthalmia, a perplexing eye disease that sometimes occurs in horses, may be prevented by the use of a riboflavin supplement.

Milk and dairy by-products, such as dried skimmilk, dried buttermilk, and dried whey, are especially rich in riboflavin. This is one of the chief reasons for the high value of milk by-products in poultry feeding. Yeast is also very

thetic riboflavin is manufactured chemically, and riboflavin concentrates are produced from bacterial cultures, or from certain fermentation residues in the production of butyl alcohol or other compounds. The riboflavin potency of these concentrates is guaranteed by the manufacturer. The riboflavin in all these types of supplements is equally available to animals, but it must be borne in mind that the synthetic riboflavin furnishes only this vitamin, while the other riboflavin supplements also supply some of the other B-complex vitamins.

213. Niacin, or nicotinic acid.—Niacin, or nicotinic acid, is a B-complex vitamin that is necessary for all animals, because it is a part of two important enzyme systems which are essential in

body metabolism. A supply in the food is, however, needed only by certain animals, including humans, swine, poultry, and dogs. A deficiency of niacin is the chief cause of pellagra, a serious disease of humans.

Ruminants, including cattle, sheep, and goats, do not need niacin in their food, because sufficient amounts are produced through bacterial synthesis in the rumen. (44) Certain other animals, including young calves, and also rats and horses, are apparently able to produce plenty of niacin in their tissues from other compounds.

Niacin is widely distributed in feeds, and ample amounts are supplied by most rations that are otherwise satisfactory. The requirements of swine and poultry, which in some cases are benefited by furnishing additional niacin, are discussed in Chapters XXXIV and XXXVI.

Recent investigations have proved that in the case of animals which require a food source of niacin, the vitamin can readily be made in the body from the amino acid tryptophan.[33] In this way tryptophan can replace niacin in the diet. This discovery explains why humans are more subject to pellagra when they live mostly on corn grain, which is very low in tryptophan, as well as being low in niacin. It also explains why there is more apt to be a deficiency in rations for pigs, when most of the feed is corn.

Experimental rations deficient in niacin cause lack of appetite in pigs, severe diarrhea, skin disease, and even paralysis of the hind quarters. It is pointed out in Chapter XXXIV that under practical conditions rations containing a liberal amount of niacin may reduce the trouble from necrotic enteritis in pigs. A lack of the vitamin in rations for dogs produces severe inflammation of the tongue and mouth, called black tongue. In chicks a deficiency of niacin causes a similar condition, and also slow growth, poor feathering, and sometimes a scaly condition of the skin. In young turkeys a lack produces a hock disorder, similar to perosis in chicks.

The amounts of niacin in important feeds are stated in Appendix Table V, so far as data are available. It will be noted that dried yeast, rice polish, rice bran, wheat bran, peanut oil meal, and green forage and pasture crops are rich in the vitamin. Barley grain, wheat grain, the sorghum grains, the oil meals, meat scrap, tankage, and fish meal are good sources. Good-quality hay supplies a fair amount, while corn grain, oats, rye, and dairy by-products have a rather low content.

Large quantities of niacin are now manfactured by synthetic chemical processes, chiefly for use in enriching bread and cereals and for other human use.

Niacin is stable in foods and is resistant to heat and oxidation. The vitamin occurs in foods not only as nicotinic acid, but also in the form of a compound called nicotinic acid amide, or nicotinamide, which is equally potent.

214. Pantothenic acid.—Pantothenic acid, earlier called the filtrate factor and the chick anti-dermatitis vitamin, is a B-complex vitamin that is needed by chickens, turkeys, pigs, dogs, foxes, and probably some other species of animals. Because of its wide distribution in feeds of both plant and animal origin, the rations commonly fed to livestock generally furnish ample amounts. It is also quite stable in feeds.

Rather restricted rations may occasionally have insufficient pantothenic acid for pigs and poultry. Therefore their requirements are discussed in later chapters. If ruminants need the vitamin, they do not require a supply in their feed, because it is synthesized by bacterial action in the rumen.

A deficiency of pantothenic acid, produced by restricted experimental rations, results in poor growth of chicks, ragged feather development, and skin disease (dermatitis), characterized by scabby sores at the corners of the mouth and on the feet, and incoordination and paralysis. In mature fowls a deficiency causes poor hatchability of eggs.

In pigs a deficiency of pantothenic acid causes poor appetite, slow growth, coughing, diarrhea, dermatitis, and stilted gait, known as "goose stepping." A lack

of pantothenic acid is one of the causes of premature graying of hair in rats, dogs, and foxes fed experimental rations deficient in the vitamin.

Large amounts of pantothenic acid are supplied by alfalfa hay and probably other good hay, by green pasture and grass crops, and by wheat bran, dairy by-products, peanut oil meal, rice bran, and cane molasses. Yeast is especially rich in the vitamin. Cereal grains and their by-products, most oil meals, beet pulp, and fish meal supply fair to good amounts. Calcium pantothenate, the calcium salt of pantothenic acid, is the pure form of the vitamin available commercially.

215. Pyridoxine.—Pyridoxine, or vitamin B_6, is a B-complex vitamin which is so widely distributed in common feeds that it is not deficient in ordinary rations for farm animals. By the use of experimental diets purposely made very low in pyridoxine, it has been found to be necessary for pigs, poultry, dogs, and rats.

A deficiency of the vitamin causes lack of appetite, poor growth, and fits or convulsions in these species. In hens it results in rapid loss of weight and in poor egg production and low hatchability of the eggs. Young pigs fed a ration lacking pyridoxine have little appetite, fail to grow, often have a type of anemia, and also may have fits. In rats a lack causes a characteristic skin disease.

Pyridoxine is apparently necessary for the formation of enzymes that are needed for the utilization of amino acids, and it also seems to be concerned with the formation of the hemoglobin of the blood.

Pyridoxine is very widely distributed in feeds of plant and animal origin, and it keeps well in storage. The cereal grains and other seeds and their by-products, and also milk, meat, fish, and cane molasses are good sources. Yeast and rice polish are especially rich in the vitamin.

Like other B-complex vitamins, pyridoxine is synthesized in the bacterial action taking place in the rumen of ruminants. Cattle and sheep are therefore not ordinarily dependent on a supply in their feed. However, it was found in Michigan studies that under certain conditions dairy cattle suffered from a peculiar disease, called poikilocytosis, which was apparently caused by a deficiency of pyridoxine, because of a lack of normal bacterial action in the rumen.[34] The condition was found chiefly in calves fed restricted rations or in older animals with an experimental rumen fistula (an artificial opening into the rumen). The trouble could be corrected by feeding pure pyridoxine or else yeast, which is rich in the vitamin.

216. Biotin.—Biotin, which was formerly called vitamin H, is a B-complex vitamin that is required by poultry, dogs, rabbits, monkeys, and probably some other species. Certain characteristic symptoms of deficiency are produced in these animals by feeding restricted rations very low in biotin. Much smaller amounts of the vitamin are needed than of most of the other vitamins, and it seems to be widely distributed in ordinary feeds. So far as is known, a deficiency of biotin does not occur in practical rations that are otherwise satisfactory for farm animals. In addition, biotin is synthesized in the rumen of ruminants, and also to some extent in the digestive tract of other animals.

In chicks a deficiency of biotin in restricted experimental rations produces symptoms somewhat like those resulting from a deficiency of pantothenic acid. Biotin is also necessary, along with manganese and choline, for the prevention of slipped tendons in chicks. In hens a lack reduces the hatchability of eggs but does not seem to decrease egg production.

Biotin deficiency can be produced in poultry and pigs by feeding too large amounts of uncooked eggs, such as waste eggs that fail to hatch in the incubator. This is because uncooked egg white contains a compound called avidin, that makes biotin unavailable. (976)

The biotin content has not been determined in many feeds, but apparently it is present in sufficient amounts in most feeds. Alfalfa hay, green forages,

grains, soybean oil meal, cane molasses, and yeast have been found to be good sources. It is very stable in feeds.

217. Choline.—Choline, one of the B-complex vitamins, has important functions in animals. It is a part of lecithin, the phospholipid which is essential in the assimilation and transport of fat. (14, 47) A compound of choline is also concerned in the transmission of nerve impulses.

When fed usual rations, most animals are able to make sufficient choline in their body tissues from other compounds to meet their needs. Also, choline is synthesized by bacterial action in ruminants. The formation of choline in the body itself seems to depend on adequate supplies of other vitamins, especially vitamin B_{12}. Poultry are able to make less choline than the larger farm animals, and shortly after birth pigs and calves have less ability to make it.

In chicks and young turkeys a deficiency of choline causes poor growth and also slipped tendons, or perosis. In mature birds a lack lowers egg production and increases mortality. Deficiency symptoms have also been produced in very young pigs and calves fed experimental rations purposely made very deficient in choline.

Certain compounds, particularly the amino acid methionine and the compound called betaine, can partially replace choline in function. Like choline, these compounds furnish labile, or readily available, methyl groups (CH_3 groups), needed in forming choline or methionine from certain other compounds. However, methionine or betaine cannot perform all the functions of choline, and do not prevent perosis.

Except in the case of poultry, most well-balanced rations for farm animals apparently have plenty of choline. While much larger amounts of choline are required by poultry than they need of the other vitamins, the amounts of choline in ordinary feeds are also far greater. For example, solvent-process soybean oil meal per pound has 1,285 milligrams of choline, while it has only 1.9 milligrams of riboflavin. (Appendix Table Va.) The choline requirements of poultry are stated in Chapter XXXVI, and the use of choline supplements discussed.

Most feeds apparently have good to fair amounts of choline. Liver meal, brewers' dried yeast, fish meal, meat scrap, tankage, soybean oil meal, cottonseed meal, and distillers solubles are rich in it. Fair sources are most grains (except corn and the grain sorghums), wheat by-products, dairy by-products, and alfalfa hay. Various choline supplements are now produced commercially, and choline is often included in the combination B-complex supplements sold for reinforcing poultry or other rations.

218. Betaine.—Betaine is not a vitamin, but it is treated here because it can partially replace choline in the diet, as it likewise furnishes readily usable, or labile, methyl groups. (217) In the same manner betaine may reduce the need for methionine, which also supplies labile methyl groups. While betaine can thus partially replace choline or methionine in this process, called transmethylation, it cannot perform the other functions of either choline or methionine. Dehydrated alfalfa, wheat bran, and wheat middlings are good sources of betaine, and presumably legume hay supplies it. Beet molasses is especially rich in it, and still richer is a concentrate prepared from a beet molasses residue, left after the commercial production of glutamic acid.

219. Folic acid, or folacin.—Folic acid, also called folacin and pteryl-glutamic acid, is a B-complex vitamin that is necessary for certain animals. It is called folic acid because it is present in the foliage of plants, and it is thus widely distributed in forages. Oil meals are good sources, and cereal grains supply some. So far as is known, folic acid is not deficient in the usual rations fed livestock.

Symptoms of folic acid deficiency produced in chicks fed highly purified diets are slow growth, poor feathering, bleaching of feathers, and anemia. It is apparently needed for good hatchability of eggs.

Synthetic folic acid is produced commercially, and is used in the treatment of certain anemias in humans.

Definite folic acid deficiency in young pigs has only been produced, even on a highly-purified ration, by administering a sulfa drug to prevent the formation of the vitamin in the digestive tract, or by feeding a substance that destroyed folic acid or prevented its action. In an experiment in which a ration made up of ordinary feeds was fed, but which was low in protein, folic acid addition tended to increase the gain of weanling pigs, but not on a ration with ample protein.[35]

220. Vitamin B_{12}.—The recent discovery, isolation, and commercial production of vitamin B_{12} is one of the most dramatic chapters in modern nutrition research.[36] This discovery, followed shortly by the commercial production of pure vitamin B_{12}, is of untold benefit to humans afflicted with pernicious anemia. Concentrated vitamin B_{12} supplements made for livestock feeding have also found wide use in rations for poultry and pigs not on pasture.

Previous to the discovery of vitamin B_{12}, it had been known that when poultry or swine not on pasture were continuously fed a ration having no protein supplement of animal origin, nutritive deficiencies often developed. Such deficiencies occurred even though the ration had ample protein and minerals and adequate amounts of all the vitamins then known. The term *animal protein factor* was used for the unknown factor or factors supplied by supplements of animal origin, such as fish meal, fish solubles, meat scrap, tankage, and dairy by-products.

Recent experiments with chicks and young pigs have shown that a large part of the beneficial effect produced by these feeds of animal origin when added to a ration entirely from plant sources, is due to the vitamin B_{12} they contain. However, as is pointed out later, such feeds also supply certain vitamins or nutritive essentials that have not yet been identified and isolated. These are called *unidentified vitamins,* or *unidentified food factors.* (222)

Because of these unidentified factors, optimum results may not be secured when chicks or pigs are kept under restricted conditions on a ration entirely from plant sources, even when all the known vitamins, including vitamin B_{12}, are supplied.

Through fine teamwork of a group of scientists, pure vitamin B_{12} was produced commercially and made available to the medical profession within four months after the discovery was first announced. This rapid development of a process for producing the pure vitamin is especially remarkable, because of the mere traces of the vitamin there are in the sources from which it can be isolated. For example, a ton of liver, one of the richest sources, contains much less than a gram of vitamin B_{12}.

The vitamin is synthesized by several kinds of micro-organisms, including some of those that produce antibiotics. Fortunately, it can be prepared commercially from the mother liquor left after most of the antibiotic is removed in the preparation of the antibiotic product. From these sources pure crystalline vitamin B_{12} is produced for use in medicine. Also from these sources *vitamin B_{12} feed supplements* are made for use in stock feeding. The vitamin B_{12} content per pound of such supplements is guaranteed by the manufacturer. Some of the vitamin B_{12} supplements contain not only the vitamin, but also guaranteed amounts of an antibiotic. Such a supplement is termed a *vitamin B_{12} and antibiotic feed supplement.* (966)

Vitamin B_{12} is the most expensive organic product made commercially, the current price being about $300.00 per gram for the pure crystalline vitamin. Nevertheless, the quantity required in a hypodermic dose for treating pernicious anemia is so small (only 15 micrograms) that the vitamin B_{12} in the dose costs less than a cent.

The high cost of the pure vitamin per gram is not surprising, considering the fact that very complicated chemical processes are required to recover the vitamin from the mere trace in the liquor from the microbial fermentation. This commonly has only 1 to 2 grams of the vitamin per ton of liquor. The price of

the vitamin in vitamin B_{12} feed supplements is much less than for the pure crystalline vitamin, because the process of manufacture is far simpler.

Vitamin B_{12} is probably needed by most animals, but it is synthesized in plentiful amounts in the bacterial fermentation that occurs in the rumen of ruminants. A certain amount of the vitamin is also apparently produced in the intestines of other animals, but the quantity thus made available to the animal is not sufficient to meet the needs of poultry and swine. They therefore need a source in their feed.

However, only very small traces of vitamin B_{12} are needed by poultry and pigs, as shown in later chapters. For example, chicks need only 4 micrograms per pound of feed. The minute size of this requirement is shown by the fact that an ounce of the pure vitamin would be sufficient for 7 million pounds of feed.

The vitamin B_{12} requirements of poultry and swine and the use of vitamin B_{12} supplements for them are discussed in Chapters XXXVI and XXXIV.

Vitamin B_{12} contains about 4 per cent of cobalt as an essential part of the vitamin. As stated in the previous chapter, it is believed that the chief cause of cobalt-deficiency troubles in ruminants is a lack of vitamin B_{12}, because of the greatly decreased formation of the vitamin in the rumen when there is a serious lack of cobalt in the food. (**175**)

The chemical name for vitamin B_{12} is cyanocobalamin. A closely related compound, Vitamin B_{12b}, seems to be equally effective in animals.

It is believed that feeds of plant origin, even green, growing forages, contain little or no vitamin B_{12}. In spite of this, young poultry or pigs on good pasture apparently have no deficiency of the vitamin, even when fed a ration that would be lacking in it if fed in dry lot.

Appendix Table Vb states the approximate vitamin B_{12} content of various feeds, so far as data are available.

221. Other B-complex vitamins.—*Inositol* and *para-aminobenzoic acid* are other B-complex vitamins that have been identified and isolated. Both are widely distributed in common feeds, and so far as is known, a deficiency of either of these vitamins does not occur in ordinary rations fed farm animals. Apparently these vitamins are synthesized in the digestive tract or in the animal tissues.

Inositol is a part of phytic acid and phytates, complex phosphorus-containing compounds in plants. (**151**) Inositol is an essential nutrient for some kinds of yeast and fungi. By feeding highly-purified diets, it has been found that it is required by certain laboratory animals and by chicks.

Para-aminobenzoic acid, abbreviated to PABA, is a relatively simple organic compound that is a part of the folic acid molecule. It is a nutritive essential for certain bacteria and for some laboratory animals. It has also been reported that para-aminobenzoic acid increased the growth of chicks fed a highly-purified diet containing none of the vitamin.

222. Unidentified vitamins.—That certain unidentified vitamins or growth factors are required by young chicks has been shown in recent experiments in which highly-purified diets have been fed, containing all the known essential vitamins, including vitamin B_{12}. These experiments are summarized in Chapter XXXVI.

At least three unidentified vitamins seem to be required by chicks, and in addition, an unknown trace mineral or combination of minerals. One of the unidentified vitamins, called the fish soluble factor, is supplied in the largest amounts by fish solubles, fish meal, liver meal, and penicillium mycelium meal. Meat scrap has somewhat less, and there is a smaller amount in dried skimmilk, dried buttermilk, and dried whey.

A second unidentified vitamin, called the distillers solubles factor, is supplied by grain or molasses distillers solubles and brewers' dried yeast. A third, called the grass juice factor, is well supplied by fresh green forage, dried whey, dried skimmilk, and brewers' dried yeast, and is also furnished by some alfalfa meal. Soybean oil meal and also grain or molasses fermentation solu-

bles have small amounts of this factor.

Recent experiments with baby pigs fed purified diets indicate that very young pigs may require similar or the same unidentified vitamins, in addition to those which have been isolated and identified.

V. Other Vitamins

223. Vitamin E.—Vitamin E is apparently concerned with several body functions, but the processes involved in certain of these are not yet known. Vitamin E was first discovered in experiments with rats, in which it was found that sterility of both males and females was produced on a highly-purified diet. This was found to be due to a lack of a vitamin, called vitamin E.

Different forms of vitamin E have been identified, which are closely related complex organic compounds called tocopherols. These not only occur naturally in plants and in animal tissues, but they have also been synthesized chemically from other compounds. Alpha-tocopherol is believed to be the most potent of the forms of vitamin E. All are soluble in fat and fat solvents.

Reproductive failure can be caused in chickens on a ration purposely made very deficient in vitamin E, but such an effect in swine is less definite. Cattle and goats have reproduced normally on rations made very deficient in vitamin E.

In some animals a serious lack of vitamin E causes a degeneration, or dystrophy, of certain muscles, including the heart. It is shown in Chapter XXXI that the "stiff lamb disease," which sometimes occurs in young lambs, can be prevented or cured by vitamin E. A deficiency of the vitamin likewise seems to be the cause of the "white muscle disease," which sometimes causes serious losses of calves, especially in certain range districts.

In Minnesota experiments reproduction was normal when dairy cattle of both sexes were fed rations devoid of vitamin E.[37] However, after cattle had been kept on an abnormal ration, devoid of the vitamin, for consecutive years, in some cases death occurred suddenly because of heart degeneration.

In New York investigations there was no improvement in the fertility of bulls used heavily in artificial insemination when wheat germ oil, which is very rich in vitamin E, was added to an ordinary ration.[38] Goats reproduced normally during successive generations in Iowa experiments when fed rations that produced reproductive failure in rats, because of the lack of vitamin E.[39] In other Iowa studies the reproductive performance of ewes fed and managed properly was not significantly improved when additional vitamin E was supplied by feeding wheat germ oil.[40]

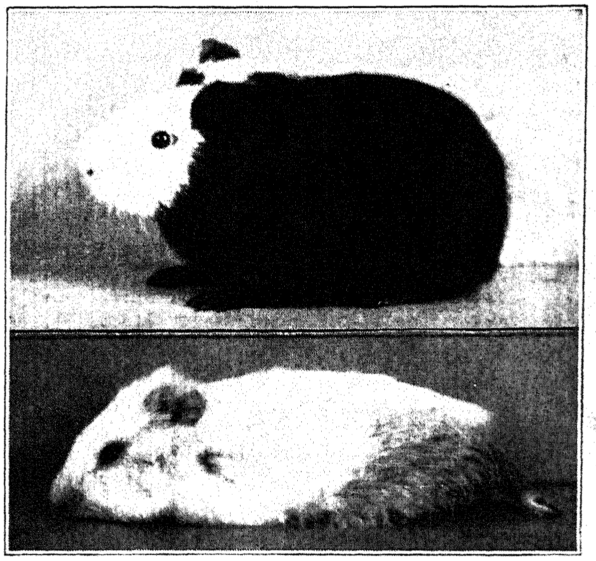
In chicks a lack of vitamin E produces the disease called nutritional encephalomalacia, or "crazy chick disease." In mature fowls a prolonged lack causes lowered hatchability of eggs and sterility of males. The exact requirements of poultry for vitamin E have not yet been determined, because most good rations seem to have adequate amounts. Further information concerning vitamin E in poultry feeding is given in Chapter XXXVI.

Vitamin E is widely distributed in livestock feeds and also in human foods that have not been too highly refined. It is abundant in the cereal grains and most other seeds, where it is present chiefly in the oil of the germ and not in the endosperm. Wheat germ oil is especially rich in vitamin E and is therefore used as a vitamin E supplement. The vitamin is also abundant in the green-leaved parts of plants and in good-quality hay, and is supplied in smaller amounts by animal tissues and eggs. Butterfat and lard have little vitamin E.

Vitamin E keeps well in ordinary feeds but is destroyed by the presence of rancid fats or other substances that favor oxidation. If concentrate mixtures are not stored too long, the vitamin E value is retained satisfactorily.

Nebraska and Minnesota experiments indicate that the usual rations fed farm animals will furnish ample amounts of vitamin E.[41] In the Nebraska studies female rats which had become infertile

on a diet deficient in vitamin E were restored to fertility when only 20 to 25 per cent of any of the following common feeds was added: Alfalfa hay, wheat bran, wheat shorts, linseed meal, hominy feed, white or yellow corn, or kafir grain. In the Minnesota experiments the following additional feeds were found to supply enough vitamin E for successful reproduction of rats, when the same proportions of these feeds were fed as are commonly used for dairy cattle: Prairie



EFFECT OF A LACK OF ASCORBIC ACID ON GUINEA PIGS

Above, a thrifty guinea pig, which received ample ascorbic acid. Below, a guinea pig suffering from scurvy, produced by a lack of the vitamin. (From Wisconsin Station.)

hay, reed canary grass hay, wheat or rye straw, oat hulls, barley grain, corn gluten meal, corn bran, dried molasses beet pulp, wheat gluten, cane molasses, meat scrap, fish meal, or blood meal.

Advertising claims have been made that the addition of wheat germ oil or other vitamin E concentrates to the usual rations for farm animals will prevent or cure sterility and be otherwise beneficial. Most nutrition authorities believe, however, that the use of vitamin E supplements for livestock is not generally beneficial, except when such a supplement is advisable to prevent one of the diseases mentioned previously. In spite of certain claims made, the addition of a vitamin E supplement to ordinary rations for dairy cows does not increase the yield of milk or raise the fat percentage.[42]

Very potent vitamin E concentrates are made commercially by extracting the small amounts in corn, cottonseed, soybean, or wheat germ oil, which contain only 0.1 to 0.3 per cent of the vitamin. Similar vitamin E supplements are made synthetically.

224. Ascorbic acid, or vitamin C.—Ascorbic acid, or vitamin C (also called the anti-scorbutic vitamin), is probably required by all species of animals. However, in most species ample amounts of the vitamin are made in the body tissues from other substances, and a supply in the food is not needed. Only human beings, monkeys, and guinea pigs lack this ability to synthesize ascorbic acid. Ordinarily, it is not necessary to give any attention to ascorbic acid in feeding farm animals.

A deficiency of ascorbic acid in man, monkeys, or guinea pigs causes scurvy. The chief symptoms of this nu-

tional disease are loosening of the teeth, inflammation of the gums, hemorrhages, brittleness of the bones, slow healing of wounds, and loss of vigor. In this country scurvy among humans has now become rare, because of the universal inclusion of fruits and vegetables in the diet, and the use of orange juice or tomato juice for young infants before they can consume other foods rich in ascorbic acid. In farm animals conditions resembling scurvy are practically unknown.

Dairy cows in South Dakota experiments had a normal content of ascorbic acid in their blood after being confined to the barn for 3 or 4 years and fed a ration having practically none of the vitamin.[43] This shows that they were able to synthesize sufficient amounts in their bodies.

Fresh fruits, vegetables, and green forages supply ascorbic acid, the content in citrus fruits, tomatoes, spinach, cabbage, and peppers being especially high. The vitamin is destroyed by oxidation in the heating of foods in the presence of air and in the drying of forage. Mature seeds and their by-products, and also hay and other dry forage, have no vitamin C. Silage may contain appreciable amounts. The vitamin is formed during the germination of seeds, and therefore sprouted seeds are rich in it.

Some of the ascorbic acid in foods is in a partially oxidized form, called dehydro-ascorbic acid. This is equal in potency to the common form, but it is readily oxidized further to inactive compounds. Ascorbic acid is soluble in water, which fact increases the loss of the vitamin in cooking by boiling, if the cooking water is thrown away.

It was suggested from studies some years ago that in some cases cattle might not form enough ascorbic acid in the body to meet their needs, and that this might be the cause of sterility in cows and bulls.[44] Although the hypodermic injection of a solution of ascorbic acid was apparently the cause of restored fertility in some instances, such results have not been secured in later tests.

Feeding ascorbic acid to ruminants does not increase the content in the body, because it is destroyed, or mostly destroyed, by the fermentations in the rumen. However, the formation of ascorbic acid in the body tissues can be increased by feeding doses of a drug called chlorobutanol.

In a recent Wisconsin experiment neither the hypodermic injection of ascorbic acid nor the feeding of chlorobutanol significantly increased the conception rate in hard-to-settle cows.[45] In a study by the United States Department of Agriculture the hypodermic injection of ascorbic acid in bulls suffering from vitamin A deficiency did not restore sexual activity or improve the potency of the semen.[46]

225. Vitamin K.—Vitamin K, the anti-hemorrhagic vitamin, is necessary, at least in some species of animals, to preserve the clotting power of the blood. If chicks are fed restricted experimental rations deficient in vitamin K, the blood will lose its power to clot and serious hemorrhages will result from slight wounds or bruises. The blood fails to clot because the vitamin deficiency results in a decrease of the prothrombin content in the blood. Prothrombin is the substance from which the enzyme is formed that clots blood when it is shed.

Fortunately, in ruminants ample vitamin K is synthesized by the bacteria in the rumen, and thus made available to the animal. The vitamin is also produced by bacteria in the intestinal tract of most animals. With the exception of poultry, in whose short intestinal tract less formation of vitamin K apparently occurs, livestock are not dependent on a supply of the vitamin in their food.

While symptoms of vitamin K deficiency are readily produced in chicks on restricted rations lacking the vitamin, symptoms of deficiency are not produced in hens fed the same ration. This is apparently because more of the vitamin is made in the intestine of the older birds. A lack of vitamin K in the ration of hens does, however, result in such a low content of the vitamin in their eggs that chicks hatched from the eggs may

bleed seriously from minor wounds, such as wing banding.

Ample amounts of vitamin K are widely distributed in green, leafy forages, either fresh or dried. Other sources are fish meal, liver, and soybeans. Since vitamin K is a fat-soluble vitamin, solvent-process soybean oil meal has little. Vitamin K has good stability in feeds.

There are several forms of vitamin K, and a synthetic compound, menadione, is produced commercially, which has an even greater anti-hemorrhagic potency than vitamin K.

Only 1 to 2 per cent of alfalfa meal of good quality usually supplies plenty of vitamin K in poultry rations, even for chicks. Recent experiments show that the requirement of poultry for the vitamin is considerably increased if there is added to the ration a high level of certain drugs, such as sulfaquinoxaline (for coccidiosis control) or arsonic acid derivatives (as a growth stimulant).[47] Hemorrhagic trouble may then occur in chicks on a ration that would be otherwise satisfactory. This can be prevented by increasing the percentage of alfalfa meal, or by adding to the ration a vitamin K supplement, such as menadione.

It has recently been reported that the addition of menadione to the concentrate mixture for dairy cows reduced the tendency for oxidized flavor to develop in milk.[48]

While vitamin K is not ordinarily of importance in the feeding of farm animals, except chicks, it is of much value in human surgery and medicine. For example, it is effective in preventing undue bleeding in certain operations and in treating hemorrhagic diseases of newborn infants.

226. Vitamin interrelationships.— Recent investigations, especially with chicks, have shown that the amounts of certain vitamins needed may be affected by the supply of another vitamin or of some other nutritive essential. The fact that niacin can be formed in the body from the amino acid tryptophan has already been mentioned. (213) Thus a liberal supply of tryptophan reduces the amount of niacin needed in the food.

It has also been shown previously that part of the functions of choline can be performed by betaine or by methionine. (217) Both these, like choline, furnish labile, or readily available, methyl groups necessary in certain syntheses in the body.

In chicks, the requirement for choline is reduced when ample vitamin B_{12} and folic acid are supplied, as these vitamins are concerned in the synthesis of methyl groups in the body. A high level of fat in the ration increases the need for choline, since choline is a part of lecithin, a phospholipid which is involved in the transport of fat in the body.

It has been shown in the preceding chapter that the requirement for vitamin D is increased if a ration has insufficient phosphorus or calcium, or if there is an improper proportion or ratio between the amounts of calcium and phosphorus.

In some experiments the addition of an effective antibiotic feed supplement to a ration for chicks has seemed to reduce the need for certain B-complex vitamins. On the other hand, the requirement for vitamin K is greatly increased by the continuous high-level feeding of certain drugs. (225)

Such relationships as these show how a lack or even an excess of one nutritive essential may affect the need for another nutrient.

QUESTIONS

1. Define *vitamin.*
2. Of what importance are green forage crops, including pasture, in meeting the vitamin requirements of farm animals?
3. What are the best substitutes for green forage crops in this respect?
4. Discuss vitamin A briefly, stating: (a) Its importance for farm animals; (b) its functions and the effects of a deficiency.
5. Explain the relationship between carotene and vitamin A.
6. Define a U.S.P. Unit of vitamin-A value.
7. Discuss the losses of carotene and vitamin A in feeds.
8. Are the following roughages rich, me-

dium, or poor in carotene content: (a) Actively-growing pasture plants; (b) mature, weathered forage; (c) green, leafy alfalfa hay; (d) corn silage; (e) alfalfa silage?

9. What is the relative carotene content of the following: (a) Yellow corn; (b) white corn; (c) barley, oats, wheat, or grain sorghums; (d) corn gluten feed from yellow corn; (e) ripe peas of green varieties; (f) soybeans; (g) carrots; (h) sweet potatoes; (i) potatoes; (j) whole milk; (k) skimmilk; (l) egg yolk; (m) tankage or meat scrap?
10. Should special concentrated vitamin-A supplements ordinarily be used for dairy cows, beef cattle, sheep, or horses?
11. Discuss the functions and importance of vitamin D.
12. What are the effects of a deficiency of vitamin D on: (a) Young animals; (b) pregnant animals; (c) mature fowls?
13. Explain the relation of light to vitamin D.
14. Of what importance is sunlight in meeting the vitamin D needs of farm animals?
15. What is the relative value of vitamin D_2 and vitamin D_3 for poultry?
16. What is the form of vitamin D in: (a) Field-cured hay; (b) irradiated yeast; (c) fish-liver oils?
17. Discuss the stability of vitamin D.
18. What is the relative vitamin D content of the following: (a) Field-cured alfalfa hay of good quality; (b) green, growing plants; (c) hay-crop silage; (d) cereal grains and by-products; (e) fish meal; (f) meat scrap or tankage?
19. What concentrated vitamin D supplements are used for poultry; for 4-footed animals?
20. What is vitamin-D milk and how is it produced?
21. Why are the B-complex vitamins not generally important in feeding cattle or sheep?
22. When might it be economical to add yeast to a ration?
23. What are the effects of a deficiency of thiamine? Is thiamine necessary in stock feeding?
24. Of what importance is riboflavin in stock feeding? What feeds are rich in riboflavin?
25. Discuss the importance of nicotinic acid in stock feeding. Name 5 feeds that are good sources of this vitamin and 4 that are rather low in it.
26. Of what importance are the following in feeding farm animals: (a) Pantothenic acid; (b) pyridoxine; (c) biotin; (d) choline; (e) folic acid?
27. Discuss the use of vitamin B_{12} feed supplements for livestock.
28. Discuss the importance of vitamin E for farm animals.
29. For what animals is ascorbic acid important? What feeds are rich in it?
30. What is the function of vitamin K? Is it important in feeding most farm animals?

REFERENCES

1. For detailed discussions of the vitamins and extensive bibliographies, see: The Vitamins, edited by Sebrell and Harris, Volumes I, II, and III, 1954.
2. Moore and Sykes, Mich., Amer. Jour. Physiol., 134, 1941, pp. 436–439; see also: Mellanby, England, Jour. Physiol., 105, 1947, pp. 382–389.
3. Madsen and Earle, U.S.D.A., Jour. Anim. Sci., 5, 1946, pp. 144–195.
4. Hale, Texas, Jour. Heredity, 24, 1933, pp. 105–106.
5. Hart and Guilbert, Cal. Bul. 560.
6. Riggs, Texas, Jour. Nutr., 20, 1940, pp. 491–500.
7. Eaton et al., Conn., Jour. Anim. Sci., 8, 1949, pp. 224–233; Wise, Caldwell, Atkeson, and Hughes, Kan., Jour. Dairy Sci., 29, 1946, pp. 515–516; Thomas, Loosli, and Willman, N.Y., Jour. Anim. Sci., 6, 1947, pp. 141–145.
8. Camburn, Ellenberger, Jones, and Crooks, Vt. Buls. 494, 509; see also: Shepherd et al, U.S.D.A. Tech. Bul. 1079. The latter publication contains an extensive bibliography.
9. Culbertson, Shearer, Hammond, and Robinson, Iowa, mimeo. rpt.
10. Colo. Rpt. 63; Magnuson, Id. Bul. 225; Mitchell and Silker, Kan., Jour. Anim. Sci., 11, 1952, pp. 72–76; Bethke, Record, and Wilder, Ohio, Poultry Sci., 18, 1939, pp. 179–187; Boucher, Penn. Bul. 480; Halverson and Hendrick, S.D. Tech. Bul. 14; Reid, Daugherty, and Couch, Tex., Poultry Sci., 34, 1955, pp. 603–608; Wall and Kelley, U.S.D.A., Ind. Eng. Chem., 43, 1951, pp. 1146–1150.
11. U.S.D.A., Agr. Res., 2, 1954, p. 16.
12. Shinn, Kane, Wiseman, and Cary, U.S.D.A., Amer. Soc. Anim. Prod., Proc. 1934; Woods, Atkeson, Wellhausen, and Johnson, Id., Jour. Dairy Sci., 19, 1936, pp. 581–596; Ham and Tysdal, Nebr., Jour. Amer. Soc. Agron., 38, 1946, pp. 68–74.
13. Watkins, N.M., Jour. Agr. Res., 58, 1939, pp. 695–699.
14. Smith and Stanley, Ariz., Jour. Agr. Res., 56, 1938, pp. 69–71; Magnuson, Id. Bul. 225; Woods, Atkeson, et al., Id., Jour. Dairy Sci., 18, 1935, pp. 547–556, 573–578, 639–645; Atkeson, Peterson and Aldous, Kans., Jour. Dairy Sci., 20, 1937, pp. 557–562; Hathaway, Davis, and Keim, Nebr. Res. Bul. 140; Wall, Okla. Bul. 242; Kemmerer and Fudge, Tex. Rpt. 1943.

15. Hanson and Loeffel, Nebr. Rpt. 1944.
16. Baltzer, Huffman, and Duncan, Mich. Quar. Bul. 25, 1942, No. 1.
17. J. H. Jones, Dickson, and J. M. Jones, Tex. Rpt. 1943.
18. Hathaway, Nebr. Res. Bul. 69.
19. Wallis, S.D. Bul. 372.
20. Johnson and Palmer, Minn., Jour. Agr. Res., 63, 1941, pp. 639–648.
21. Ewer, British Jour. Nutr., 5, 1951, pp. 287–300.
22. Yoder and Thomas, Iowa Rpt. 1951, Part 2.
23. Keener, N.H., Jour. Dairy Sci., 37, 1954, pp. 1337–1345; Newlander and Riddell, Vt., Jour. Anim. Sci., 11, 1952, pp. 419–421; Wallis, Smith, and Fishman, Jour. Dairy Sci., 32, 1949, p. 715.
24. Skory and Hartwig, N.Y. (Cornell) Memoir 313.
25. Newlander, Vt., Jour. Dairy Sci., 31, 1948, pp. 455–460; see also: Thomas and Moore, U.S.D.A., Jour. Dairy Sci., 34, 1951, pp. 916–928.
26. Thomas, U.S.D.A., Jour. Dairy Sci., 35, 1952, pp. 1107–1116.
27. Moore et al., U.S.D.A., Jour. Dairy Sci., 31, 1948, pp. 489–499.
28. Newlander, Jones, and Foote, Vt. Bul. 561.
29. Bechtel, Huffman, Duncan, and Hoppert, Mich., Jour. Dairy Sci., 19, 1936, pp. 359–372.
30. Madsen, McCay, Maynard, Davis, and Woodward, N.Y. (Cornell) Memoir 178; Davis, Maynard, and McCay, N.Y. (Cornell) Memoir 217; see also: Blaxter and Brown, British Jour. Nutr., 7, 1953, pp. 287–298.
31. McElroy and Goss, Cal., Jour. Nutr., 20, 1940, pp. 527–550; 21, 1941, pp. 163–173, 405–409; Teeri, Josselyn, Colovos, and Keener, N.H., Jour. Dairy Sci., 34, 1951, pp. 1070–1072; McCay, Maynard, Loosli, and Johnson, N.Y. (Cornell) Rpt. 1940; Hunt et al., Ohio, Jour. Nutr., 21, 1941, pp. 85–92; 25, 1943, pp. 207–216; Bechdel, Honeywell, Dutcher, and Knutsen, Penn., Jour. Biol. Chem., 80, 1928, pp. 231–238; Kesler and Knodt, Penn., Jour. Dairy Sci., 34, 1951, pp. 145–148; Pearson, Winegar, and Schmidt, Tex., Jour. Nutr., 20, 1940, pp. 551–563; Wegner, Booth, Elvehjem, and Hart, Wis., Soc. Expt. Biol. and Med. Proc., 47, 1941, pp. 90–94; Pearson, Struglia, and Lindahl, U.S.D.A., Jour. Anim. Sci., 12, 1953, pp. 213–218.
32. Carroll, Goss, and Howell, Cal., Jour. Anim. Sci., 8, 1949, pp. 290–299.
33. Krehl, Teply, Sarma, and Elvehjem, Wis., Science, 101, 1945, p. 489; Henderson, Ramasarma, and Johnson, Ill., Jour. Biol. Chem., 181, 1949, p. 731; Luecke, McMillen, Thorp, and Tull, Mich., Jour. Nutr., 36, 1948, pp. 417–434.
34. Reid, Huffman, and Duncan, Mich., Jour. Dairy Sci., 30, 1945, pp. 413–423.
35. Cunha, Hodgskiss, Rasmussen, and Colby, Wash., Jour. Anim. Sci., 9, 1950, pp. 73–77.
36. Rickes et al., Science, 107, 1948, p. 396; 108, 1948, p. 634.
37. Gullickson et al., Minn., Jour. Dairy Sci., 32, 1949, pp. 495–508.
38. Salisbury, N.Y., Jour. Dairy Sci., 27, 1944, pp. 551–562.
39. Thomas, Cannon, McNutt, and Underbjerg, Iowa, Jour. Nutr., 15, 1938, No. 6, Sup., pp. 10–11; Iowa Rpts. 1937, 1938, 1939.
40. Thomas, LaGrange, and Culbertson, Iowa, Jour. Anim. Sci., 1, 1942, p. 61.
41. Hathaway and Davis, Nebr. Res. Bul. 73; Palmer, Nelson, and Gullickson, Minn., Jour. Dairy Sci., 1940, pp. 571–572.
42. Gullickson, Fitch, and Gilmore, Minn., Jour. Dairy Sci., 31, 1948, pp. 557–560; Whiting, Loosli, Krukovsky, and Turk, N.Y., Jour. Dairy Sci., 32, 1949, pp. 133–138; Phillips, Kastelic, and Hart, Wis., Jour. Nutr., 36, 1948, pp. 695–701; Neilsen, Denmark, Jour. Dairy Res., 20, 1953, p. 333.
43. Wallis, S.D., Jour. Dairy Sci., 1943, pp. 401–408.
44. Phillips, Lardy, Boyer, and Werner, Wis., Jour. Dairy Sci., 24, 1941, pp. 153–158.
45. Christian, Ulberg, Phillips, and Casida, Wis. and U.S.D.A., Jour. Dairy Sci., 34, 1951, pp. 978–987.
46. Madsen et al., U.S.D.A., Jour. Anim. Sci., 7, 1948, pp. 60–69.
47. Sweet, Romoser, and Combs, Md., Poultry Sci., 33, 1954, pp. 430–432.
48. Krienke and Arrington, Fla., Jour. Dairy Sci., 37, 1954, pp. 640–641.

CHAPTER VIII

MAINTAINING FARM ANIMALS

I. Requirements for Heat and Energy

227. Maintenance needs of animals.—On the average, fully one-half the feed eaten by farm animals is used merely to maintain the necessary life processes. Only the remainder of the food can be converted into such useful products as meat, milk, eggs, work, or wool. It is therefore highly important to understand the maintenance requirements of animals.

The amount of food that is needed merely to support an animal when doing no work and when yielding no product, is called a *maintenance ration*. When an animal receives a maintenance ration, its body will neither gain nor lose in protein, fat, or mineral matter.

To maintain an animal at rest without losing or gaining in weight, it must have adequate supplies of the following: (1) Heat to maintain the body temperature; (2) energy to carry on the vital functions, such as breathing; (3) protein to repair the small daily waste of protein tissues; (4) mineral matter to replace the small but continuous loss of minerals; (5) vitamins; (6) water; and (7) air. In addition to these nutrients, the requirements for which are discussed in this chapter, it has been shown in Chapter V that at least young calves, lambs, pigs, and chicks need a very small amount of fat or of certain fatty acids for health. (133)

228. Maintaining the body temperature.—The average body temperature of the larger farm animals is not far from 100° F., differing somewhat with the various species of animals and also slightly with individual animals of the same species. Since the body temperature of warm-blooded animals is higher than the air temperature, except on the hottest summer days, it is evident that heat must normally be produced in their bodies to keep them warm.

Heat is produced by all the oxidations which take place in the body, no matter whether of food yet in the digestive tract, or of nutrients in the muscles and other tissues of the body. In the case of animals exercising normally, the greater part of the heat is produced in the muscles, since all muscular contraction is caused by the oxidation of nutrients in the muscles. Even when the muscles are not actively contracting, they are in a state of some tension, and a certain amount of heat is being produced in them.

It has been shown in Chapter III that considerable heat is produced, especially in the case of ruminants, in the fermentations of carbohydrates that occur in the digestive tract. Also, all the energy that is used up in the digestion and assimilation of food and in other forms of internal work is finally changed to heat. (68) Though this energy is lost so far as useful production is concerned, the resulting heat helps to maintain the body temperature. Even with such an easily digested feed as corn, about one-third of the total energy in the digested nutrients is unavoidably converted into heat in this "heat increment," or so-called "work of digestion." With roughages, such as hay and straw, the proportion of energy that is thus converted into heat is much larger.

Unlike the burning of fuel in a stove, the oxidations in the body take place at a comparatively low temperature. In still another respect, the body oxidations differ radically from ordinary burning of fuel. In a furnace the wider the draft is opened, increasing the supply of oxygen, the more rapid will be the combustion. However, in the body, so

long as there is a normal supply of oxygen, the rate of burning of the food nutrients is independent of the supply of air. Hence, the greater intake of oxygen in unusually deep breathing will not in itself cause an increase in heat production, though the increased muscular work in such breathing may lead to a slight increase in the production of heat.

229. Normal body temperatures of different farm animals.—The normal temperature of different animals of the same species may vary considerably. On the other hand, the temperature of an individual animal, if healthy, varies only within a narrow limit, a departure of even one degree from normal with farm animals generally indicating some bodily derangement.

The normal body temperatures of various farm animals are as follows: [1] For dairy cows the range is 100.4—102.8° F. (38.0—39.3° C.) and the average is about 101.5° F. (38.6° C.). For beef cows the range is 98.0—102.4° F. (36.7—39.1° C.) and the average is about 101.0° F. (38.3° C.). For sheep the range is 100.9—103.8° F. (38.3—39.9° C.) and the average 102.3° F. (39.1° C.). For horses the range is 99.0—100.8° F. (37.2—38.2° C.) and the average about 99.8° F. (37.7° C.). For swine the range is 101.6—103.6° F. (38.7—39.8° C.) and the average about 102.5° F. (39.2° C.). Chickens have a distinctly higher body temperature, with a range of 105.0—109.4° F. (40.6—43.0° C.) and an average of 107.1° F. (41.7° C.) during the daytime.

230. Regulation of body temperature.—Not only must heat be continuously produced in the body, but the temperature must be kept constant under varying external conditions and with supplies of food that differ in heat-producing power. This is done by the unconscious regulation of both the loss and the production of heat.

Extensive studies are being conducted by various laboratories, especially by Brody and associates at the Missouri Station in cooperation with the United States Department of Agriculture, on the effects of air temperature, of humidity, and of air movement and other factors on heat production and control of body temperature in farm animals.[2] Other studies on these subjects are being carried on by the United States Department of Agriculture at Beltsville, Maryland, by the California, Louisiana, and Texas experiment stations, and by scientists in India and some other tropical and semi-tropical countries.[3] Thus far, most of these investigations have been with cattle, which suffer greatly in too hot weather.

Except in very hot weather, the most important means of regulating the loss of heat is by varying the circulation of blood near the surface of the body. When the body temperature rises, more blood flows to the capillaries of the skin, where some of the heat passes off into the air. It is this which causes the flushing of the skin when one becomes heated.

If this means of control is not sufficient to keep the body temperature normal, sweat is produced in the case of animals that can sweat appreciably. If the animal has only a few sweat glands or if these are not well developed, it will begin to breathe more rapidly or to pant. This increases the loss of heat by vaporizing water from the lungs and mouth. The respiratory surface, mostly in the lungs, is far larger than the external body surface, and it is all moist, so water can be evaporated from it. In man, the respiratory surface is said to be at least 30 times the external body surface.

Unless the air temperature is as high as the body temperature, more rapid breathing also increases the loss of heat by warming the air breathed in and out.

Even in the case of animals that do not produce visible sweat, a considerable part of the heat loss is through the evaporation of water from the surface of the body in the form of insensible perspiration, in which there is no visible sweat on the skin. This is an important means of controlling the body temperature in cattle, in which the sweat glands are poorly developed, except on the nose. In Illinois tests, even at an air temperature of 69° F., as much as 40 to 50 per cent of the total loss of heat from the body was by vaporization of water (including the loss both from the skin

and from the lungs).[4] At higher temperatures the loss of heat by these means was still greater.

In the Missouri studies, the loss of heat by cattle in insensible perspiration was small at comfortable air temperatures, but amounted to as much as 70 per cent of the total heat dissipated at an air temperature of 95° F.

Animals use other means of heat control in hot weather. If it is available, they will seek shade, where it is cooler. A pig will try to keep cool by wallowing in water or mud, in order to increase the heat loss by wetting the skin. Also, a pig may burrow into cool earth.

In addition to these means of regulating the body temperature, the clothing of man, and in other animals the hair, wool, feathers, thick skin, or blanket of fat under the skin check and control the loss of heat from the body. For example, a bird can check the loss of heat in cold weather by ruffling up its feathers. Similarly, the loss of heat in an animal may be checked by the hair being more erect when it is cold. Also, when an animal is sleeping, it will tend to curl up if it is cold and to stretch out when it is hot, thus decreasing or increasing the amount of body surface exposed.

231. Controlling the production of heat in the body.—When the temperature of the air is too cold, then the production of heat in the body must be speeded up. This is done by increasing the oxidations in the muscles and other tissues. On cold days animals eat more heartily and take more exercise than in warm weather, both of which result in the production of more heat. A low air temperature may also cause an involuntary stimulation of the oxidations going on in the muscles, which may even become visible in the shivering of the chilled animal. The shivering is caused by the muscular contractions that occur involuntarily in order to produce more heat.

The temperature of the air below which the oxidations in the body must be increased to keep an animal warm is called the *critical temperature* for that animal. The exact temperature will depend on the species of animal; on its coat of hair, wool, or feathers; on its degree of fatness; and, especially, on how liberally it is being fed.

The critical temperatures for farm animals with winter coats and which are fed maintenance rations are probably somewhat below 60° F. For fasting animals with normal coats the critical temperatures usually range between 60° and 70° F.[5] In the case of a man wearing ordinary clothing the critical temperature is about 49° F., and for swine it has ranged from only 52° F. or less, to 68° F.[6]

In the case of liberally-fed dairy cows or full-fed fattening animals, much heat is unavoidably produced in the mastication, digestion, and assimilation of the large rations. Except in unusually cold weather, the heat thus formed is sufficient to keep them warm, and they are not benefited by warm quarters. In such animals the critical temperature is very low.

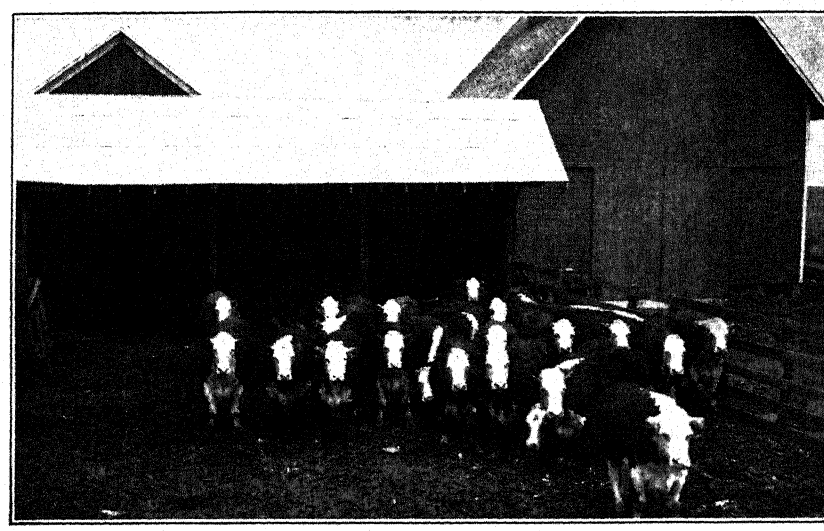
Any external conditions that increase or decrease the loss of heat from the body affect the critical temperature. For example, wind striking the body continuously removes the layer of partially-warmed air next to the skin, and thus increases the loss of heat. Therefore a cold temperature is felt much more on a windy day, and wind makes hot weather less uncomfortable. Moistness of the air increases the conducting power of the hair, wool, or clothing, and therefore animals feel the effects of damp, cold weather much more than of dry cold.

Above the critical air temperature for an animal, the rate of metabolism remains rather constant with a rise in air temperature, until the air becomes so hot that the body temperature increases. This then causes greater heat production through speeding up metabolism, in spite of the animal already being too hot. If the animal suffers so much from heat that appetite fails, then less heat may be produced, because of the decrease in heat increment. (68)

232. Shelter needed by farm animals.—The requirements of each class

of farm animals for shelter are discussed in the respective chapters of Part III. For the reason just stated, warm stables are not needed for well-fed dairy cows. Similarly, cattle and sheep fattened during the winter in cold climates will make as economical gains when housed in an open shed as in a warmer stable.

In the case of animals that are fed less liberally, feed may be saved by providing more shelter from the cold. Very young animals need warmer quarters in cold weather than older ones, because the temperature regulating mechanism is not yet well developed in the body. Thus, brooders are needed for young chicks raised artificially. Pig brooders are beneficial to young pigs in cold weather. Very young dairy calves should also have reasonably warm quarters.



FATTENING STOCK DO NOT NEED WARM SHELTER

Heavily-fed fattening steers need no winter shelter except an open shed, for an abundance of heat is unavoidably produced in the digestion of their liberal rations. On the other hand, animals being carried through the winter on scanty rations may require less feed in warmer quarters.

233. Effect of hot weather.—In very hot weather the body temperature may rise considerably, in spite of all the efforts to keep it normal. In other words, the animal will have a fever, because of the excessive heat.

Under such conditions the milk yield of cows of our dairy breeds is reduced considerably, and growing or fattening animals make less rapid gains. If the animals are subjected to very hot weather for a long period, their health may even be affected. Brody well summarizes the importance of the effect of hot weather as follows: "The serious agricultural problem in most parts of this country is not how to keep adult farm animals warm in winter, but how to keep them cool in summer."[7]

Much can be done to keep animals more comfortable and thus maintain satisfactory production in hot weather. Shade should be provided for stock on pasture, because an animal may absorb much more heat from the direct rays of the sun than is produced in the body itself.[8]

In hot climates, if there are no shade trees in pastures, portable or other shades should be made. Experiments in the hot Imperial Valley of California showed that the roof of a shade for cattle should be about 10 to 12 feet from the ground, in order to allow good move-

ment of air.[9] The roof should be of insulating material, like hay, or of reflecting material, like aluminum. The shade should be large enough to accommodate the animals without crowding together, as this lessens heat loss from their bodies.

In these California studies, with an average air temperature of 91.8° F., fattening cattle provided with cooled drinking water (65° F.) gained 0.26 to 0.44 lb. more a day than others getting uncooled water (89° F.).

much more heat and absorbs less than does long, wooly hair, such as our beef breeds tend to have. Such a coat is a benefit in cold weather but a detriment in heat.

In hot weather animals are more comfortable on a green, growing pasture than in a bare paddock.[11] This is because the air temperature near the ground in the pasture is appreciably lower, due to the evaporation of water from the growing plants. When the weather is hot, stock on pasture graze much less than normal during the heat of the day and less total time in the 24 hours.[12] They will therefore not get their fill unless there is an abundance of palatable forage.

SHADE SHOULD BE PROVIDED IN HOT WEATHER

In hot weather stock on pasture should be provided with shade. Where there are no shade trees in the pasture lot, a cheap movable shelter will furnish shade.

Anything that restricts good air movement is detrimental to stock in hot weather. Wire-fence corrals are therefore preferable to small, heavy wooden corrals. The latter not only hinder free air movement, but also reflect and radiate heat.

The absorption of heat from sunlight is decidedly less in the case of animals with light-colored coats than by those with dark coats.[10] This is because more of the rays are reflected from the light-colored coat. It is of interest to note that most of the native breeds of cattle in tropical countries have light-colored coats, usually gray or light fawn-colored. A dense, short, glossy hair coat reflects

In very hot weather swine, which have poor ability to get rid of excess heat, suffer much less if they can wallow in water. This should be provided in a concrete wallow, or a portable metal wallow, which can be kept sanitary, and not by a filthy mud hole. Another method of letting swine get their skin wet is to let water trickle over a clean concrete floor in a hog pen.

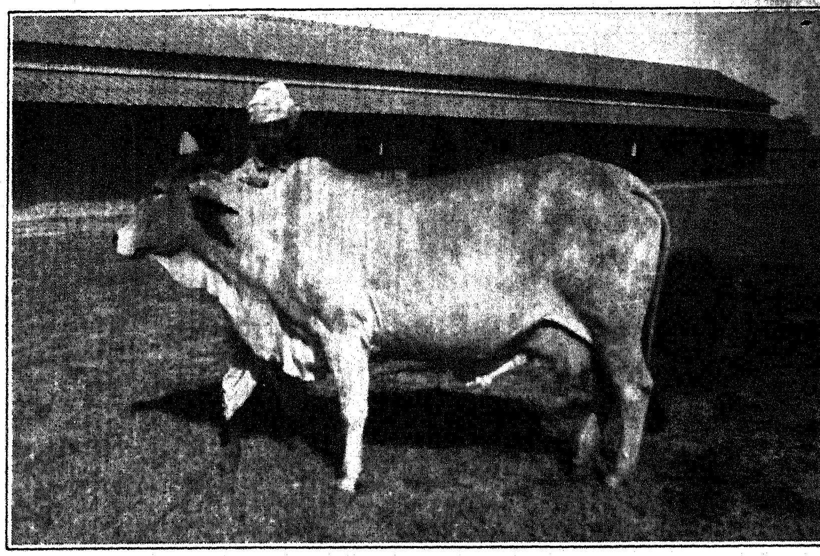
Experiments have been conducted

to find whether an automatic sprinkling device that produces a very fine spray would increase the milk yield of dairy cows in hot weather. The results thus far reported have not been encouraging.[13]

Animals can stand much hotter weather in a dry climate than where the humidity is high. This is because the animal can get rid of less heat by the evaporation of water when the air is moist. The effect of high humidity is much less in the case of cattle than for animals that can sweat freely.[14]

234. Heat tolerance of various farm animals.—The various kinds and breeds of livestock differ greatly in their ability to endure hot weather. The breeds and breeding of farm animals are outside the scope of this volume, and therefore only certain general statements concerning this matter are made here.

The European breeds of cattle do not thrive under tropical conditions where Zebu cattle (also called Brahman, Indian, or Pakistani cattle) do well. Afrikander cattle also tolerate heat. In some tropical countries the native cattle, developed over hundreds of years in the hot climate, stand the climate well, but they are nearly all low producers of milk or beef.



ZEBU CATTLE CAN ENDURE EXTREMELY HOT WEATHER

Zebu cattle tolerate very hot weather much better than cattle of the European breeds. This may be partly due to a more extensive development of sweat glands. This Zebu cow was the highest producer in the dairy herd at the Karnal Breeding Station in India at the time of a visit there by the author. She yielded 7,000 lbs. of milk in her first lactation and over 10,000 lbs. in her second.

Among the European breeds, Brown Swiss and Jerseys tolerate heat much better than Holsteins, Ayrshires, Herefords, Aberdeen-Angus, or Shorthorns. In the Missouri studies with cows, the marked increase in body temperature and the decline in feed consumption and milk production with increasing air temperature, began at about 70° F. with Holsteins, 75° with Jerseys, 80° with Brown Swiss, and 90 to 95° with Brahmans.

Because the infusion of Zebu blood greatly increases the tolerance to heat, cross breeding with Zebus is widely practiced in tropical and semi-tropical regions. Such cross breeding is common in commercial beef herds in Florida and in the Gulf Coast district of this country

where the summers are hot and humid.

From surveys the author has made of livestock production in Venezuela and the Philippines, he is convinced that beef production can be greatly increased in such regions by introducing Brahman or other Zebu blood into the native cattle.

In order to combine the superior beef-producing ability of the European beef breeds with the heat tolerance of Zebus, the Santa Gertrudis breed was developed by the King Ranch of Texas, combining the blood of Shorthorns and of Brahmans.[15] Other cross-bred breeds being developed are the Brangus, the Braford, the Charbra, and the Beefmaster.

It is more difficult to develop high-producing dairy cattle suited to very hot regions, because most of the Zebu breeds are low producers of milk. Among such breeds that have fair milk-producing ability are the Red Sindhi, a breed of very small cattle, and the Tharparker and Sahiwal breeds.

Experiments are being conducted by the United States Department of Agriculture and some of the southern experiment stations in which the blood of Red Sindhis is being combined with that of Jerseys and other European breeds. Similar breeding investigations are being carried on in Jamaica and in other tropical regions.

Part of the greater ability of Zebu or Brahman cattle to endure heat is undoubtedly due to the fact that they have a larger skin area per 100 lbs. of weight than do the European breeds. This is because of the pendulous dewlap and navel fold, the long ears, and the hump. The greater surface area is a decided benefit to them in hot weather, but it is a disadvantage in very cold weather, as it increases the heat loss from the body.

In the Missouri studies, the Brahman cows had a lower rate of metabolism and consequently of heat production than cows of European breeds. This was partly, but not entirely, due to their much lower milk production. Contrary to some opinions, the Brahman cattle did not sweat visibly at high air temperatures. Nevertheless, they were able to get rid of more heat by evaporative especially at high humidity, t cattle of European breeds.

In bringing animals into a h mate from a cooler region, they should reach the hot district at a cooler part of the year, so they can gradually become accustomed to the heat. In cattle the heat tolerance is lowest for calves, and it increases gradually up to about 4 years of age.

Water buffaloes can endure heat and humidity well, if they can immerse themselves in water or mud each day, or if their coats are wet, by splashing water on them. This is in spite of the fact that they are dark in color. Horses stand tropical climates better than the European breeds of cattle, and mules and donkeys have even greater heat tolerance.

The author was surprised to find in a survey he made of the livestock industry of the Philippine Islands that the improved breeds of swine get along much better than European breeds of cattle under tropical conditions, if they are provided with water wallows and strict attention is given to sanitation.

235. Energy required for vital functions.—In a maintenance ration a certain amount of net energy must be supplied for the various activities of the body when it is idle. Even when an animal is not eating food or assimilating a meal, energy is required for the work of the heart, lungs, and other internal organs. Also, nutrients are constantly being oxidized in the muscles to keep them in a state of tension. In the case of most animals more nutrients must be oxidized when they are standing than when they are lying at rest, as the muscles are under greater tension. If an animal moves about, a still larger amount of energy is needed for the movements.

The amount of energy needed for all these purposes is relatively small, however, for an animal that is being maintained at rest in a stall. The greater part of the food is required merely as fuel to keep up the body temperature. For example, to maintain a horse at rest only one-third of the total energy of the

t·..ion need be supplied in the form of net energy, the remainder being used solely to warm the body.

Maintenance rations for livestock, except swine and poultry, may therefore consist largely of roughages, such as hay and straw, which furnish abundant heat, but which do not yield a large amount of net energy. Since the ration must furnish at least a minimum amount of net energy, animals cannot be maintained without loss of weight on such a feed as wheat straw alone, which furnishes no net energy to horses and but little to ruminants.

236. Total digestible nutrients required for maintenance.—Numerous studies have been made of the amounts of total digestible nutrients or of energy required for the maintenance of farm animals. One method of conducting such experiments is to find the minimum amount of a suitable ration that will actually maintain the animal over long periods in a thrifty condition, without loss of weight. In such experiments care must be taken that the ration contains adequate supplies of protein, minerals, and vitamins.

Unless such investigations are continued for long periods, the results may not be accurate. The animal may not lose weight, even when there is some loss of protein or fat, because there may be a compensating increase in the water content of the body. However, when such experiments are conducted for many months and with a sufficiently large number of animals, they provide the most reliable data concerning the actual amounts of nutrients required for proper maintenance.

The most extensive of such studies are those of Hills and associates, who conducted investigations on the maintenance requirements of dairy cows at the Vermont Station over a period of 13 years. These studies showed that a ration having 6.48 lbs. of total digestible nutrients was sufficient for the maintenance of a 1,000-lb., dry, non-pregnant cow. It has been shown previously that a liberal ration is not digested and utilized quite so completely as a scanty ration. (101) For this reason a well-fed cow in milk undoubtedly needs more feed for mere maintenance than if she were fed a scanty ration which would maintain her weight when dry.

The available information concerning the maintenance requirements of each of the classes of stock is presented in the chapters of Part III. The Morrison feeding standards, which are given in Appendix Table III, state the amounts of nutrients that in the opinion of the author should be provided for maintaining various classes of farm animals. The standards for maintaining dairy cows and for wintering beef breeding cows, brood mares, ewes, and brood sows, provide not only enough nutrients for maintaining the mother, but also for the development of the bodies of the unborn young. (288–292)

It should be borne in mind that the amounts of nutrients recommended in these standards are not the theoretical minimum requirements, but are allowances of nutrients that should be safe under varying practical conditions. In other words, the standards provide a reasonable margin of safety to cover the considerable variations in the requirements of individual animals, in the composition of feeds, and in other conditions.

237. Basal metabolism; resting metabolism.—Another method of studying the maintenance requirements for energy is to determine in a respiration apparatus or calorimeter the amount of heat produced by an animal when at rest, and when a sufficient time has elapsed since the last meal so that there is no longer an increased production of heat due to the digestion and assimilation of food. This is called the *basal metabolism*, or the fasting metabolism, of the animal. Such determinations cannot be made until considerable time has elapsed since food has been eaten, because the heat production of the body is greatly increased while food is being assimilated. Thus, in New Hampshire experiments dry cows produced 50 to 60 per cent more heat on a maintenance ration than on the second day of fast.[16]

In determinations of the basal metabolism of humans, the experiments are made 12 to 18 hours after the last meal. In the case of farm animals, especially ruminants and

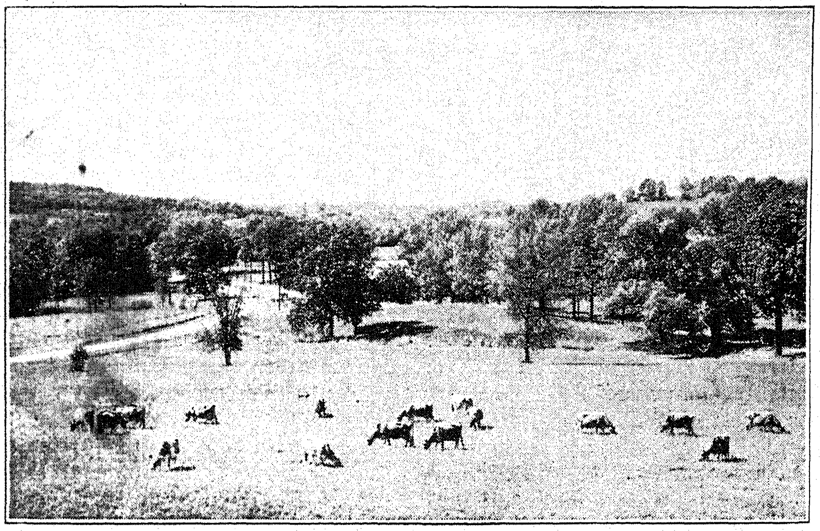
horses, a much longer period of fasting is required to reach the same state. This is because of the slow passage of feed through their digestive tracts. Therefore, what is termed the *resting metabolism* is sometimes determined, the experiments being conducted 12 hours after the last meal. This resting metabolism may be considerably higher than the theoretical basal metabolism.

The basal metabolism does not represent the total amount of nutrients or energy required for maintenance, but only the minimum amount of energy expended by the animal when at rest and consuming no food. To this amount must be added the amount used in the heat increment. Also, the amount of energy expended in the normal motions of the animal must be added to the basal metabolism.

From studies at the Missouri Station, Brody and associates have concluded that the maintenance requirements of mature animals at air temperatures above the critical temperature are about twice the basal metabolism.[17] At lower temperatures, as in the case of animals exposed to winter temperatures in the northern states, the maintenance requirements would be higher.

238. Maintenance requirements not proportional to weight.—In the older feeding standards it was assumed that the amounts of feed required for maintaining animals of the same kind but of various live weights depended on their weights. It has been found, however, that maintenance requirements are generally more nearly proportional to the amount of body surface than to the live weight. Thus, a cow weighing 1,600 lbs. does not require twice as much total digestible nutrients for maintenance as does one weighing 800 lbs. Similarly, the 800-lb. cow does not need anywhere near eight times as much nutrients for maintenance as a sheep weighing 100 lbs.

This condition is due to two factors: First, the chief loss of heat from the body is by radiation and conduction from the body surface. Therefore the loss is proportional to the amount of surface. Large bodies have less surface per pound than do smaller ones. Thus, the 1,600-lb. cow has much less body surface than two 800-lb. cows. Second, the weight of the most active tissues of the body (the internal organs, the glands, etc.) in animals of different sizes is more nearly proportional to the surface of their bodies than to their live weights.



ONE-HALF THEIR FEED IS NEEDED FOR MAINTENANCE

Even good dairy cows require for the mere maintenance of their bodies about one-half of the total feed they consume. Only the remainder can be used for milk production.

The amount of nutrients needed for the muscular work of holding the body upright and of moving about, presumably depends on the live weight. However, animals of large size may be less active than smaller ones of the same kind. This would tend to offset the difference due to weight.

From studies at the Missouri Station, Brody and associates concluded that the maintenance requirements for total digestible nutrients or energy of mature animals of various sizes are proportional to the 0.7 power of the live weight.[18] (The body surfaces of animals of various sizes are proportional to the 0.66 power of their live weights.) Kleiber of the California Station has reached similar conclusions.[19]

On the other hand, Gaines of the Illinois Station concluded from studies of the results of feeding experiments that the maintenance requirements of dairy cows were proportional directly to their live weights.[20]

The results of these various studies have been considered in the amounts of nutrients recommended for animals of various sizes in the Morrison feeding standards. The amounts of nutrients advised for maintaining dairy cows of various weights are proportional to the 0.87 power of the live weight. This factor was chosen since rations computed on this basis seemed to agree best with the methods of feeding good dairy cows that have proven satisfactory in practice.

239. Factors affecting maintenance requirements.—In feeding livestock it is important to bear in mind that any factor which decreases the digestibility or utilization of feed will increase the amount required for maintenance. Also, any condition that needlessly increases the oxidations in the body tissues will increase the maintenance requirements. Thus, a quiet animal needs less food for maintenance than a nervous, active one. This is one of the main reasons why a fattening animal that "eats and lies down" makes the most economical gains.

Exposure of animals to cold air temperatures increases the loss of heat by radiation, especially if they have scanty coats.[21] If their coats are wet by cold rain or snow, still more heat is lost, for the cold water must be warmed and evaporated by heat produced through oxidation of food. With well-fed fattening animals, the greater loss of heat through these causes may not produce any waste of food, because much more heat is being produced in the work of digesting the liberal ration than is ordinarily needed to warm the body. On the other hand, animals being carried through the winter on scanty rations have no such excess of heat, and therefore much feed may often be saved by protecting them from cold winds and storms.

As has been pointed out previously in this chapter, too high an air temperature will increase the maintenance requirements. (231)

Young animals require considerably more feed to maintain them at constant weight than mature animals of the same size or body weight.[22] This is due to a higher rate of metabolism and at least partly to their greater activity. Males of dairy cattle and swine have higher maintenance requirements than females per unit of weight, according to Missouri tests.[23] Castrated male cattle or sheep had about the same maintenance requirements as females.

Horses have higher maintenance requirements than cattle of the same weight, because they are more active. Also, the requirements are much higher for Thoroughbred horses than for draft horses, because of the great difference in temperament.[24]

It has already been mentioned that with most animals more nutrients must be oxidized when an animal is standing up than when lying down. With cattle and sheep, the increase averaged only about 9 per cent in Missouri tests.[25] Horses used no more nutrients and in some cases even less when standing than when lying down. This is perhaps the reason why many horses prefer to sleep standing up.

When an animal that has been more

liberally fed is first put on a maintenance ration, more feed may at first be required to maintain its weight than later. Apparently, after it has been on the scanty food supply for some time, it gets on a more economical basis and is able to digest and utilize its feed more efficiently. However, if an animal is unthrifty, because of semi-starvation or illness, its maintenance requirements will be higher than normal.

An animal requires more feed to maintain its live weight after it is fattened than before. This is partly because it is heavier and has a larger body surface. Also, the fat condition itself may increase the maintenance requirements per unit of weight or body surface.[26] In very cold weather, however, a blanket of fat may reduce the maintenance need, by insulating the animal against the cold.

240. Source of nutrients during starvation.—When an animal is given no food, the heat needed to warm the body, the net energy required to carry on the vital processes, and the protein and mineral matter necessary for the repair of the active tissues must all come from nutrients previously stored within the body. The small supply of glycogen in the liver and muscles is probably first used as fuel, but this is soon gone. Fat is the animal's chief reserve fuel, stored when food is abundant, against times of scarcity, and is therefore the main source of both heat and energy during starvation.

When the supply of fat begins to fail, the muscles and other protein tissues are broken down more rapidly to furnish heat and energy, and the animal finally perishes through the impairment of its organs and the lack of body fuel to carry on the functions of life. Carnivora, or flesh-eating animals, withstand hunger longer than herbivora. While dogs and cats have lived until their weights were decreased 33 to 40 per cent, horses and ruminants will die when their weight has been reduced 20 to 25 per cent.

Men have survived fasts of 30 to 75 days, and dogs have endured fasts of from 90 to 117 days without permanent ill effects. The age of the animal influences the time at which death occurs from starvation, young animals losing weight more rapidly and dying after a smaller loss of weight than old ones.

II. Requirements for Protein, Minerals, and Vitamins

241. Protein requirements for maintenance.—The heat and energy required to maintain the body can be furnished by feeding carbohydrates and fat. However, an abundant amount of these nutrients alone will not maintain an animal, for there must be a supply of protein to replace the daily break-down or wear of the protein tissues of the body. Likewise, there must be protein for the growth of the hair or wool and of the skin and hoofs, which are all composed chiefly of protein.

Because protein-rich foods are generally more expensive than those rich in carbohydrates, it is of much importance to know the minimum amount of protein needed to maintain animals in good health. Fortunately, the daily need of protein for mere body maintenance is relatively small. When ample amounts of carbohydrates and fats have been provided, dry cows and steers have been maintained on only 0.5 to 0.6 lb. of digestible protein daily per 1,000 lbs. live weight, and in some instances on even a smaller allowance.[27]

The amounts of digestible protein advised in the Morrison feeding standards for maintaining various classes of stock are based upon studies by the author of the results of feeding trials conducted by various experiment stations. Slightly larger amounts of protein are recommended than are theoretically necessary for mere maintenance. For example, 0.60 to 0.65 lb. of digestible protein is recommended for maintaining a 1,000-lb. dairy cow. It is believed that these allowances of protein will safely cover the variations in the composition of feeds that have been discussed in Chapter IV. (**95–100**) Also, this maintenance allowance will provide the relatively small additional amounts of protein needed for the development of the unborn calf until the last few weeks of pregnancy, when an additional allowance is advised.

In the opinion of the author it is

generally unwise to feed rations that supply decidedly less protein than recommended in these feeding standards. As has been explained in a previous chapter, when stock are fed rations exceedingly low in protein, the digestibility of the protein and other nutrients is often seriously decreased. (**102**) This causes a wastage of feed. In addition, a supply of protein somewhat above the minimum apparently promotes the health of animals. In well-fed animals there is a small but important reserve supply of protein in the blood and tissues. It is believed that animals with a good protein reserve are better able to resist infection, because the antibodies are produced from the serum protein of the blood.

While we generally speak of the protein requirements of animals, undoubtedly what the body really needs is not a certain amount of protein, but definite amounts of the various essential amino acids. For maintenance, the food must therefore provide not only a certain amount of protein, but also the protein must be of proper quality for the particular class of animal.

The amounts of digestible protein advised in the Morrison feeding standards are recommended on the assumption that reasonable care will be taken to provide protein of a quality that is satisfactory for the particular class of animal. The quality or kind of proteins in various feeds and rations has been discussed in detail in Chapter V.

Experiments indicate that the amounts of digestible protein required for the maintenance of animals of the same kind but of various sizes are not strictly proportional to their live weights.[28] Instead, the protein needs are proportional to the 0.7 power of the live weight, the same as in the case of the requirements for total digestible nutrients. These experiments have been taken into consideration in the amounts of digestible protein advised in the Morrison feeding standards.

242. Studying protein needs on a protein-free ration.—Some studies on the protein requirements of animals have been conducted by determining the amounts of protein lost from the body on a ration containing no protein, but which supplies an abundance of carbohydrates and fat. On such a ration, the amino acids needed for maintenance must be secured by a gradual tearing down or wasting away of the protein tissues of the body.

From such experiments and from similar investigations of others, Mitchell and associates have concluded that the 1,000-lb. animal will lose about 0.175 lb. protein daily on a protein-free ration, and that twice this amount of digestible protein in the food, or only 0.35 lb., is enough for maintenance.[29] This purely theoretical conclusion is based on the assumption that the proteins in the usual maintenance ration can be used for the repair of body tissue with an efficiency of 50 per cent. However, the author believes this is an unsafe protein allowance for maintenance, because it has not been proved in long-time feeding experiments that animals can actually be maintained in good health on such a small amount.

Other experiments have been conducted in which all food has been withheld from animals for varying lengths of time. When an animal is given no food, the nitrogen excretion (representing the loss of protein from the body) decreases rapidly at first, until the supply of amino acids in the blood and tissues, which have not yet been built into body protein, is lowered to a minimum.

The nitrogen waste in the urine then slowly decreases until it reaches a level that remains quite constant so long as heat and energy are furnished by the body fat. When the supply of the latter begins to fail, the muscles and other protein tissues must thereafter not only furnish protein for the repair of the vital body machinery, but they must also supply the necessary heat and energy. Consequently they waste more rapidly until death follows.

We might expect that when protein only is fed to a fasting animal, in an amount corresponding to the quantity lost daily during starvation, it would replace the protein wasted from the tissues, and the animal thus be brought to nitrogen equilibrium; that is, it would excrete as much, but no more, nitrogen than was contained in the food. However, when practically pure protein is fed, the loss of nitrogen can be stopped only if the supply is far in excess of the waste from the starving body. This is probably because the tissues are flooded with amino acids, the product of protein digestion, and

the wastage through deaminization is therefore greatly increased. (**51**)

When animals are fed exclusively on nitrogen-free nutrients, such as sugar, starch, or fat, the wasting away of the muscles and other protein tissues of the body is somewhat reduced, though not entirely stopped. Therefore, animals forced to live on such a diet survive longer than those wholly deprived of food. Yet, because of the continuous small waste of protein from the tissues of the body, animals nourished solely on fats and carbohydrates cannot long survive.

243. Mineral requirements for maintenance.—The necessity of an adequate supply of minerals in maintenance rations has been shown experimentally by giving animals sufficient food, but food from which the minerals have been removed as completely as possible. Even though the rations contain an abundance of protein, carbohydrates, and fat, the animals will die from mineral starvation, and generally the end will come sooner than if no food at all is given. The importance and functions of each of the necessary mineral nutrients have been discussed in Chapter VI, and further information concerning the mineral requirements of each class of stock is given in the chapters of Part III.

When an animal is merely being maintained, it is making no growth in skeleton or protein tissues, and it is yielding no product such as milk. Therefore the mineral requirements for maintenance are relatively small, particularly in comparison with those for growth or for milk production.

However, even when livestock are not being fed for production, common salt should ordinarily be supplied. Care must also be taken that the ration provides the small amounts of calcium and phosphorus needed to replace the daily losses from the body. In most regions other necessary minerals are usually furnished in sufficient amounts by the ordinary feeds.

244. Vitamins required for maintenance.—Detailed information has been presented in the preceding chapter on the functions and importance of each of the vitamins. Specific recommendations concerning the vitamin requirements of each class of stock are given in the respective chapters of Part III. Most of the vitamin investigations have been conducted to find the vitamin needs for growth, milk production, or egg production, and but little information has been secured on the maintenance requirements. It is known, however, that mature animals can be maintained in good health on decidedly smaller supplies of vitamins than are needed by growing animals or by mature animals that are producing milk or eggs. Nevertheless, to make sure that there will be no injury from a lack of vitamins, one should see that even maintenance rations provide an ample supply, especially of vitamins A and D.

245. Nutritive requirements in later life.—Very few experiments have been conducted, even with small laboratory animals, to study the nutritive requirements in later life and the effect of the diet on the length of life. Practically no information on this subject has been secured with farm animals. The limited amount of data secured with small animals indicates that the thrift and vitality of mature animals and their length of life can be definitely increased by supplying more than the bare minimum amounts of certain essential nutrients.

In extensive experiments by Sherman and associates at Columbia University, groups of rats were fed throughout life upon a ration that supported normal growth and health, with successful reproduction and rearing of young for generation after generation.[30] Other groups were fed the same, except that the proportion of milk in the diet was increased. This supplied more than the minimum amounts of high-quality protein, of calcium, of vitamin A, and of riboflavin.

The more liberal amount of milk not only increased the rate of growth and development, but also resulted in better adult vitality and appreciably extended the average length of adult life. These rats maintained the full vigor of the prime of life into the period when the other rats, fed merely a minimum diet, became definitely senile. Similar results

were secured by Orr and associates in experiments with rats in Scotland when additional milk and green food were added to a diet like that often consumed by man.[31] In further experiments by Sherman and associates it was found that the more liberal supply of calcium accounted for a large part of the improvement in the diet containing more milk.

Experiments by Henry and Kon in England and also by McCay and associates at Cornell University indicate that in later life animals are not able to use calcium as efficiently as when they are younger.[32] In the English experiments old rats steadily lost calcium from their bodies on a diet that had supplied enough of this mineral when they were younger. It was necessary to greatly increase the calcium content of the diet to get these old rats back into calcium balance. The results were similar in the New York experiments, except that in the case of old dogs it was impossible to keep them from losing some calcium from the body, even on a calcium-rich diet.

In other studies by McCay and associates on the nutritive requirements of rats during the latter half of life, it was found that a factor of great importance in determining the length of life was the degree of fatness. Rats that were not allowed to become fat outlived those that became fat.[33] Exercise was of minor importance, except as exercise reduced the tendency to lay on fat. A reasonable excess of protein over the minimum was not harmful, but too high an intake was less favorable.

III. Additional Requirements

246. Air requirements; ventilation of stables.—While animals can go without food for considerable periods, complete lack of air brings sudden death, since a continuous supply of oxygen is required for all vital processes. There is no lack of oxygen in the air of any ordinary stable, even if it is not especially ventilated. However, for other reasons an efficient ventilation system should be provided in closed stables. Proper ventilation consists of maintaining a comfortable stable temperature and a relatively low humidity of the air without drafts.[34]

We have all experienced the ill effects of poorly-ventilated rooms. These effects include depression, drowsiness, headache, and a reduced ability to do mental or physical work. It was formerly believed that the bad effects of a lack of ventilation were due to a lack of oxygen or to an accumulation of carbon dioxide, and also to a poisonous or injurious substance in the air breathed out by animals. Experiments have proved that these beliefs were untrue. Enough air enters any ordinary stable or room through crevices, etc., to prevent a lack of oxygen or an injury from too much carbon dioxide in the stable air. However, there are other reasons for providing an efficient ventilating system in stables.

A good ventilating system will make the animals more comfortable, for it will prevent the air in the stable becoming too humid, or high in moisture, due to the water vapor in the air exhaled. Also, in warm weather a ventilating system will aid in keeping the temperature of the stable comfortable, because of the circulation of air. Proper ventilation will also get rid of foul odors.

247. Other benefits of ventilation.—One of the most important benefits from proper ventilation of a stable, along with suitable insulation of the walls, is that it prevents the condensation of moisture in cold weather. In a stable without a ventilating system, water will often condense on the walls and windows to such an extent that serious rotting of the timber results. Moreover, so much water may condense in the hay mows as to cause spoilage of the hay. The coats of the animals may also become damp, causing discomfort or even disease. Because good ventilation keeps the stable much drier than otherwise, it helps prevent bacterial growth. There is thus apt to be more trouble from disease when a stable is poorly ventilated.

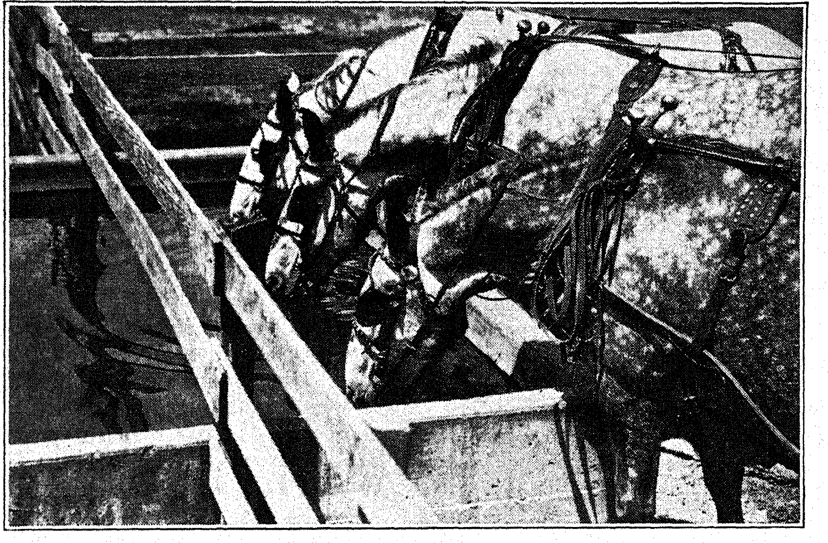
248. Water.—An abundant supply of water is needed for all the vital processes of the body, such as the digestion

and absorption of food nutrients and the removal of waste from the body. As shown previously in this chapter, water is also exceedingly important in regulating the body temperature.

Farm animals should have all the water they care to drink, for they do not take an excessive amount unless they are given salt irregularly or are forced to live on very watery foods. When water is not provided so that stock can drink whenever they are thirsty, they should be watered at regular intervals. In order to avoid disease, the water should be of safe quality. Also, if the water is not palatable, animals may not drink enough for the best results.

Animals must bring up to the body temperature all the water that they drink, thus using up heat. This does not mean that food is always wasted when cold water is warmed within the body. Animals may have an excess of heat which has been unavoidably produced in the work of digesting their food and converting the nutrients into body products or work.

However, when animals are watered only once a day, they then drink a large amount. In winter, if the water is cold, this makes a sudden demand for such a large amount of heat that food may be burned simply to warm the water, even though at other times there may be an excess of heat in the body. For this reason, feed may be saved by allowing animals exposed to cold and those fed scanty rations, to have frequent access to water, or else by warming the water. The chief advantage from heating stock-watering tanks in winter in cold climates is that it keeps them free of ice so the stock can get all the water they want at any time.[35]



FARM ANIMALS SHOULD HAVE PLENTY OF WATER

All classes of stock should have all the water they will drink. Horses doing hard work in summer need an especially liberal supply, and they are benefited by watering them at reasonably frequent intervals.

Under normal conditions animals consume a fairly uniform quantity of water for each pound of dry matter eaten. If some of the feed is succulent, such as silage, roots, or green forage, the amount of water that is drunk will be correspondingly reduced.

When entirely oxidized in the body, 100 lbs. of carbohydrates will yield 55.5 lbs. of water and 163 lbs. of car-

bon dioxide, and fats over twice as much water. The nitrogenous compounds yield a little less, because they are not entirely oxidized in the body. This shows that the animal gets some water from the dry matter of the food.

The water requirements of each class of stock are discussed in detail in Part III.

249. Saline and alkaline water.—In the drier districts water sometimes contains so much soluble mineral salts that it is unsuitable for stock. It was found in studies by the Oklahoma Station that the limit of tolerance depended on the kind of animal, the age, and the season of the year.[36] It made little difference whether the total quantity of dissolved salts was made up of a single salt or a number of salts.

It was concluded that 1.5 per cent of total salts in the water was about the safe upper limit for satisfactory maintenance. For lactating animals the limit was lower. Sheep were able to exist when the water contained 2.0 per cent or more of minerals. From Colorado studies it was concluded that even considerably lower percentages of salts in water retarded the gains of fattening animals.[37]

Animals seem to become accustomed to drinking water that is unsatisfactory at first. If good water is readily accessible, they never drink water having a harmful amount of minerals.

250. Softened water.—Claims were recently made that dairy cows produced more milk when supplied with water softened by means of a commercial water softener, than when they had hard water. However, in experiments at three experiment stations softening hard water for dairy cows did not result in any increase in milk production or have any favorable effect on the cows.[38]

251. Urinary calculi.—Sometimes male cattle and sheep, especially fattening animals, are seriously affected by the formation of urinary calculi in the bladder or kidneys. These not only cause great pain but may cause death through blocking the flow of urine, even resulting in the rupture of the bladder. The calculi are usually composed largely of mineral matter, especially phosphates or in some cases silicates. Horses or swine are rarely troubled with urinary calculi.

Several experiments have been conducted in an endeavor to find the cause of calculi and ways of preventing their occurrence.[39] However, the definite information on the subject is still very limited, because the results of the studies have been conflicting.

252. Possible causes of urinary calculi.—The trouble from calculi may be increased if animals consume an excessive amount of minerals. This may result either from mixing an undue amount of minerals in the concentrates, or from supplying a mineral mixture flavored with molasses.

The results have differed widely in trials in which the relationship of phosphorus to urinary calculi has been studied. In some experiments a low amount of calcium and a large amount of phosphorus has seemed to be a cause of calculi, and the addition of calcium carbonate has been beneficial. In certain tests the feeding of considerable wheat bran or wheat middlings, both very high in phosphorus, to fattening steers or lambs has apparently increased the trouble. However, in other experiments the addition of bone meal to a fattening ration has seemed to reduce the cases of calculi.

Insufficient water to drink may cause the trouble, as the urine is then more concentrated, and solids are more apt to separate out. Therefore, it is important that the animals have access to a convenient supply of good water. It is surprising that in one trial the rams in a lot that drank the most water had the most trouble from calculi. Salt should always be available to the animals.

There seems to be more trouble from calculi when sweet sorghum forage (either silage or dry fodder) is fed than on other rations, and also when the grain is grain sorghum, instead of corn. In certain trials sugar beet tops or beet top silage has increased calculi. **(643)** Feeding enough alfalfa hay in addition to sorghum forage or beet tops, has

seemed to reduce the trouble. A possible reason why sweet sorghum forage may increase cases of calculi is that it is high in silicates.

Rations seriously deficient in vitamin A apparently tend to produce calculi, although opinions differ as to whether a lack of vitamin A is a common cause of the trouble. The formation of calculi seems to be prevented by good-quality alfalfa hay and especially by the combination of alfalfa hay and yellow corn, both of which supply vitamin A value.

253. Feeding concentrates alone to stock.—It would ordinarily be very uneconomical to feed cattle, sheep, or horses on nothing but grain and other concentrates, because concentrates are usually much more expensive than roughages. Still more important is the fact that good roughages, such as pasturage, well-cured hay, and silage, are exceedingly important as sources of vitamins and minerals.

As a matter of scientific interest, numerous experiments have been conducted to find whether various farm animals can live on concentrates alone.[40] When cattle or sheep are fed concentrates alone, without any roughage, rumination usually ceases or is greatly decreased.

Except for a tendency to bloat, cattle and sheep may get along fairly well on concentrates alone for several months, if care is taken to provide sufficient amounts of minerals and of vitamin A and vitamin D. However, when such a ration is long continued, nutritive deficiencies usually develop, probably caused by a lack of dietary essentials that have not yet been discovered.

Many attempts have been made to raise calves on milk alone or on milk and concentrates.[41] The earlier tests usually soon ended in failure, for they were conducted before the importance of minerals and vitamins was well understood. Later trials have been successful over a longer period, when great care has been taken to add mineral and vitamin supplements to the ration. Even in these, the animals have finally developed severe nutritive deficiencies, resulting in death.

Pigs have been raised with fair success on whole milk plus minerals, without grain or roughage. Under practical conditions it is exceedingly important to furnish swine with well-cured legume hay whenever they are not on pasture. This helps to provide their vitamin needs, as well as supplying calcium and protein.

An attempt to feed horses on oats alone ended in failure, for in a few days they refused the oats and drank but little water.[42]

254. Succulent feeds.—Scientific experiments and common farm experience have abundantly demonstrated the value of adding succulent feeds to the rations of livestock. Just as our own appetites are stimulated by fruits and vegetables, succulent feeds are relishes for farm animals, inducing them to eat more feed and convert it economically into useful products. The beneficial laxative effect of silage and other succulent feeds aids in keeping stock healthy. Also, succulent feeds may stimulate digestion, because of their palatability.

It is shown in later chapters that when silage is added to a satisfactory winter ration made up of dry feeds for the feeding of dairy cows or fattening cattle or sheep, generally the production will be very appreciably increased. The increase in milk yield or in rate of gain will be large, unless the dry roughage is of very excellent quality. On the other hand, if the stock are fed an abundance of high-quality legume hay or even mixed hay, there may be but little improvement through adding silage or any other succulent feed. The decision as to whether or not to feed silage under such conditions should be reached after considering the various factors discussed in Chapter XV.

255. Exercise.—Exercise is essential to maintain health. The only exceptions to this rule are fattening animals, soon to be marketed, which make more rapid gains if not allowed to move about too freely. Abundant exercise is of especial importance with breeding animals. The exercise requirements of the various

farm animals are discussed in the respective chapters of Part III.

256. Sunlight.—Opinions differ concerning the importance of sunlight in stables for livestock. Adequate windows seem highly desirable to the author, as well-lighted stables are probably more sanitary in most cases than those that are poorly lighted. Not only may sunlight have a germicidal effect, but also caretakers are more apt to keep a well-lighted stable clean.

Sunlight which has not passed through window glass produces vitamin D in the body, as has been pointed out previously. (201)

QUESTIONS

1. Define a *maintenance ration*. Name 7 essentials for the maintenance of an animal.
2. Describe the production of heat in the body and state how it differs from the burning of fuel in a stove.
3. Describe three ways in which the loss of heat from the body is regulated.
4. Explain what is meant by the *critical temperature.*
5. Why are warm quarters not needed in winter for well-fed dairy cows or fattening stock?
6. What is the effect of very hot weather on stock?
7. How can farm animals be made more comfortable in very hot weather?
8. What is the relative heat tolerance of: (a) European breeds of cattle; (b) Zebu cattle; (c) horses and mules; (d) swine?
9. In maintaining a mature animal, for what purpose is most of the feed needed?
10. How can the amount of total digestible nutrients be determined that is required to maintain a mature animal?
11. What is the relationship between the amounts of total digestible nutrients required for maintenance by animals of various live weights?
12. How do the following affect the amount of feed an animal requires for maintenance: (a) Restlessness; (b) a fat condition of the animal; (c) exposure to cold weather?
13. Discuss the protein requirements for the maintenance of mature animals.
14. What 3 mineral nutrients should be especially considered in maintenance rations?
15. Compare the vitamin requirements for maintenance with those for growing animals or for those producing milk.
16. What is known about the nutritive needs in later life?
17. Why is a good system of ventilation advisable in closed stables?
18. Discuss the water requirements of farm animals.
19. How can trouble from urinary calculi be lessened?
20. What nutritive deficiencies are encountered when calves are raised on nothing but milk and concentrates?
21. Discuss the importance of: (a) Succulent feeds; (b) exercise; (c) sunlight.

REFERENCES

1. Dukes, The Physiology of Domestic Animals, 7th Ed., 1955, p. 638.
2. Brody, Ragsdale, Thompson, Kibler, Worstell, et al., Mo. Res. Buls. 425, 433, 435, 436, 449, 450, 451, 461, 464, 471, 473, 479, 481, 485, 497, 515, 521, 522, 531, 542, 545, 552, 556, 561, 562, 574, 576, 578, and 579.
3. McDowell, Lee, Fohrman, and Anderson, U.S.D.A., Jour. Anim. Sci., 12, 1953, pp. 573–581; McDowell, Lee and Fohrman, U.S.D.A., Jour. Anim. Sci., 12, 1953, pp. 747–756; Lee, McMullan, McDowell, and Fohrman, Johns Hopkins Univ. and U.S.D.A., Jour. Anim. Sci., 13, 1954, p. 1024; McDowell, Lee, McMullan, Fohrman, and Swett, U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 1420–1428; Garver, U.S.D.A., Refrig. Eng., 63, 1955, p. 64; McDowell et al., U.S.D.A., Jour. Anim. Sci., 14, 1955, p. 1250; Ittner, Guilbert, and Carroll, Cal. Bul. 745; Heitman and Hughes, Cal., Jour. Anim. Sci., 8, 1949, pp. 171–181; Heitman, Hughes, and Kelly, Cal. and U.S.D.A., Jour. Anim. Sci., 10, 1951, pp. 908–915; Ittner, Bond, and Kelly, Cal., Jour. Anim. Sci., 13, 1954, pp. 867–877; Carroll, Rollins, and Ittner, Cal., Jour. Anim. Sci., 14, 1955, pp. 218–223; Branton, Johnston, and Miller, La., Jour. Dairy Sci., 36, 1953, pp. 585–586; Johnston, Miller, Frye, and Vizinat, La., Jour. Dairy Sci., La., 38, 1955, pp. 617–618; Stone and Johns, La., Jour. Dairy Sci., 38, 1955, p. 614; Kunkel, Stokes, Anthony, and Futrell, Tex., Jour. Anim. Sci., 12, 1953, pp. 765–770; Quazi and Schrode, Tex., Jour. Anim. Sci., 13, 1954, pp. 1028–1029; Cartwright, Tex., Jour. Anim. Sci., 14, 1955, pp. 350–352; Arrillaga, Henning, and Miller, Puerto Rico and Penn., Jour. Anim. Sci., 11, 1952, pp. 50–60; Riek and Lee, Australia, Jour. Dairy Res., 1948, pp. 219–232; Mullick, Murty, and Kehar, India, Jour. Anim. Sci., 11, 1952, pp. 42–49.
4. Mitchell and Hamilton, Ill. Rpt. 1932.
5. Capstick and Wood, Jour. Agr. Sci., England, 12, 1922, pp. 257–268; Magee, Jour. Agr. Sci., England, 14, 1924, pp. 506–515; Forbes et al., Penn., Jour. Agr. Res., 33, 1926, pp. 579–589; Mitchell and Haines,

Ill., Jour. Agr. Res., 34, 1927, pp. 549–557; Brody, Bioenergetics and Growth, 1945, p. 294.
6. Ritzman and Colovos, N.H. Tech. Bul. 75.
7. Brody, Bioenergetics and Growth, 1945.
8. Riemerschmid, Jour. South African Vet. Med. Assoc., 14, 1943, pp. 121–141; see also: Gaalaas, U.S.D.A., Jour. Dairy Sci., 28, 1945, pp. 555–563.
9. Ittner and Kelly, Cal., Jour. Anim. Sci., 10, 1951, pp. 184–194; Ittner, Bond, and Kelly, Cal., Jour. Anim. Sci., 13, 1954, pp. 867–877; Ittner, Guilbert, and Carroll, Cal. Bul. 745.
10. Fla. Rpt. 1944; Rhoad, U.S.D.A., Amer. Soc. Anim. Prod., Proc. 1940; Riemerschmid, Jour. South African Vet. Med. Assoc., 14, 1943, pp. 121–141; Bonsma, Farming in South Africa, Feb. 1943.
11. Regan and Richardson, Cal., Jour. Dairy Sci., 21, 1938, pp. 73–79; Cal. Rpt. 1936–38.
12. Seath and Miller, La., Jour. Dairy Sci., 29, 1946, pp. 199–206; Miller, La., Jour. Anim. Sci., 10, 1951, pp. 961–968.
13. Ky. Rpt. 1949; Seath and Miller, La., Jour. Dairy Sci., 31, 1948, pp. 361–366; Miller et al., La., Jour. Anim. Sci., 10, 1951, pp. 961–968.
14. Thompson, Worstell, and Brody, Mo. Res. Bul. 531; Seath and Miller, La., Jour. Dairy Sci., 29, 1946, pp. 465–472.
15. Breeding Beef Cattle for Unfavorable Environments, a Symposium at the King Ranch Centennial, edited by A. O. Rhoad, 1955.
16. Ritzman and Benedict, N.H. Bul. 250.
17. Brody, Bioenergetics and Growth, 1945.
18. Brody, Procter, and Ashworth, Mo. Res. Bul. 220; Brody, Bioenergetics and Growth, 1945.
19. Kleiber, Cal., Hilgardia, 11, 1932, No. 11; Kleiber, Cal., Amer. Soc. Anim. Prod., Proc. 1936.
20. Gaines, Ill. Jour. Dairy Sci., 20, 1937, pp. 583–598; 29, 1946, pp. 259–272.
21. Hogan, Salmon, and Fox, Mo. Res. Bul. 18.
22. Trowbridge, Moulton, and Haigh, Mo. Res. Bul. 18; Brody et al., Mo. Res. Bul. 166; Ritzman and Colovos, N.H. Tech. Buls. 75, 80.
23. Brody et al., Mo. Res. Bul. 166; see also: Ritzman and Colovos, N.H. Tech. Bul. 75.
24. Ritzman and Benedict, N.H. Buls. 296, 331.
25. Hall and Brody, Mo. Res. Bul. 180; Winchester, Mo., Sci., 97, 1943, p. 24; Brody, Kibler, and Trowbridge, Mo. Res. Bul. 368; see also: Forbes, Kriss, Braman, et al., Penn., Jour. Agr. Res., 35, 1927, pp. 947–960; Mitchell and Hamilton, Ill. Rpt. 1927; Ritzman and Benedict, N.H. Tech. Bul. 45.
26. McCandlish and Gaessler, Iowa Res. Bul. 60; Armsby and Fries, Penn., Jour. Agr. Res., 9, 1917, p. 451.
27. Hills, Vt. Bul. 226; Perkins, Ohio Bul. 389; Armsby, the Nutrition of Farm Animals, pp. 323–332.
28. Smuts, Jour. Nutr., 9, 1935, pp. 402–433; Terroine and Sorg-Matter, Arch. Internat. Physiol., 29, 1927, p. 121; 30, 1928, p. 115; Sorg-Matter, Arch. Internat. Physiol., 30, 1928, p. 126; Brody, Bioenergetics and Growth, 1945.
29. Mitchell, Nat. Research Council, Bul. 67.
30. Sherman, Chemistry of Food and Nutrition, 7th Ed., 1946; Science News Letter, May 18, 1946.
31. Orr, Thompson, and Garry, Jour. Hygiene, 35, 1935, pp. 476–497.
32. Unpublished results by Henry and Kon, cited by Kon, Jour. Royal Soc. of Arts., England, 93, 1945, p. 122; Kane and McCay, N.Y., Jour. Gerontology, 2, 1947, p. 244; McCay et al., N.Y. (Cornell) Rpts. 1949, 1950.
33. McCay, Maynard, Sperling, and Osgood, N.Y., Jour. Nutr., 21, 1941, pp. 45–60.
34. For a more detailed discussion of the ventilation of barns, see: Kelley, U.S.D.A. Tech. Bul. 187; Armsby and Fries, Penn., Jour. Agr. Res., 21, 1921, pp. 343–368.
35. Anderson, Foster, and Gobble, Ind. Rpt. 1942.
36. Heller, Okla. Bul. 217; see also: Ramsay, Agr. Gaz., N.S. Wales, 35, 1924, pp. 339–342.
37. Colo. Rpt. 1941.
38. Graf and Holdaway, Va., Jour. Dairy Sci., 35, 1952, pp. 998–1000; Blosser and Soni, Wash., Jour. Dairy Sci., 36, 1953, pp. 596–597; Allen, Wis., unpublished data.
39. Newsom, Tobiska, and Osland, Colo. Tech. Bul. 31; Colo. Farm and Home Res., 4, 1954, No. 5; Beeson, Pence and Holm, Id., Amer. Jour. Vet. Res., 4, 1943, pp. 120–126; Swingle and Marsh, Mont., Amer. Jour. Vet. Res., 14, 1953, pp. 16–18; Harris and Alexander, Nebr. Quarterly, 2, 1953, No. 2; Eveleth, Bolin, Goldsby, and Ford, N.D. Bimo. Bul., 10, 1948, No. 5; Ore. Buls. 477, 491, 508; Jones, Keating, Ellis, and Crookshank, Tex. Prog. Rpt. 1570; Tex. Bul. 724; Schneider, Taysom, and Ham, Wash. Stas. Cir. 203; Lindley, Taysom, Ham and Schneider, Wash., Jour. Anim. Sci., 12, 1953, pp. 704–714; Wyo. Rpt. 61; Earle and Lindahl, U.S.D.A., Jour. Anim. Sci., 10, 1951, p. 1046; Earle and Lindahl, U.S.D.A. Agr. Res., 2, 1953, No. 2.
40. Mead and Goss, Cal., Jour. Dairy Sci., 18, 1935, pp. 163–170; 19, 1936, pp. 465–466; Cole and Mead, Cal., Science, 98, 1943, pp. 543–544; Mich. Rpt. 1932–34; Gullickson, Minn., Jour. Dairy Sci., 20, 1937, pp. 419–420; Ritzman and Benedict, N.H. Bul. 289; Sanborn, Utah Bul. 21; Miller, Amer. Dairyman's Assoc., Rpt. 1874.
41. Mead and Goss, Cal., Jour. Dairy Sci., 18, 1935, pp. 163–170; Davenport, Ill. Bul. 46; Cannon, Iowa Res. Bul. 136; Cave et al., Kan. Rpt. 1932–34; Huffman, Conley, Lightfoot, and Duncan, Mich., Jour. Nutr., 22, 1941, pp. 609–620; Wise, Gullickson, and Petersen, Minn., Jour. Dairy Sci., 22, 1939, pp. 573–582; Herman, Mo. Res. Bul. 245; Knoop, Krauss, and Hayden, Ohio, Jour. Dairy Sci., 22, 1939, pp. 283–289; Thomas and Okamoto, U.S.D.A., Jour. Dairy Sci., 37, 1954, p. 656; Parr and Allcroft, Proc. British Nutr. Soc., 12, 1953, p. VII.
42. Patterson, Md. Bul. 51.

CHAPTER IX

GROWTH—FATTENING—REPRODUCTION

I. Growth

257. Importance of thrifty growth.—Growth is one of the most important forms of livestock production. While the maximum productive possibilities of any animal depend on its inherited characteristics, its full capacity cannot be reached unless it is properly fed during the growing period.

Growth is the foundation of meat production in all classes of stock. Young cattle, sheep, and swine will not make economical gains while being fattened, unless they have been raised so that they are thrifty and vigorous. Likewise, one cannot expect good yields of milk from dairy cows, unless they have been well developed as heifers.

Similarly, brood mares, beef cows, and ewes may have their productive ability seriously reduced if they have been raised improperly. Work horses and mules cannot perform the maximum amount of labor if their growth has been stunted or if their skeletons have been injured by inadequate rations during the growth period.

258. Requirements for growth.—The nutritive requirements for growth are very different from those for mere maintenance. Not only are far greater amounts of certain nutrients required, but also a young, growing animal suffers sooner and much more seriously from nutritive deficiencies than does a mature animal.

In comparison with mature animals that are merely being maintained at constant weight, growing animals need: (1) Decidedly more protein and protein of better quality; (2) much more total digestible nutrients; (3) a more liberal supply of minerals, especially calcium and phosphorus; and (4) larger amounts of vitamins.

Each of these needs is discussed in the following articles, and detailed information is given in Part III concerning the requirements of each kind of young stock. Many different rations are suggested there and in Appendix Table VII which will produce good growth and development. The nutritive requirements for growth of each kind of the larger farm animals are stated in the Morrison feeding standards. (Appendix Table III.) The requirements of poultry are given in Chapter XXXVI.

259. Protein requirements.—Since growth consists largely of an increase in the size of the muscles and other protein tissues, it is obvious that far more protein is needed for growth than for maintenance. Also, the quality or kind of protein is more important for growing animals than for those that are merely being maintained. (111) If there is an inadequate supply of any of the essential amino acids, an animal will be unable to make normal growth, even though the *amount* of digestible protein is plentiful. As has been emphasized in Chapter V, after the rumen has become well developed in ruminants, the quality of protein in the ration is of far less importance for them than for poultry or pigs.

Very young animals require the largest proportion of protein in their rations, because of the extremely rapid growth of protein tissues in their bodies. The proportion of protein that is needed gradually decreases as the animals become older and store less protein and more fat.

The amounts of digestible protein recommended in the Morrison feeding standards are based on the results of actual feeding experiments with the various kinds of young animals. Since the amounts of protein in individual lots of

the same kind of feed vary considerably, safe allowances for such variations have been included in the recommendations. In the standards it is assumed that protein of satisfactory quality will be furnished in the ration.

Recent experiments, reviewed in Chapter XXXIV, have shown that when a ration for growing pigs supplies ample amounts of vitamin B_{12} and the other essential vitamins, somewhat less protein is needed for excellent gains than was previously thought to be necessary. It thus seems that the benefit from the former more liberal allowance of protein was due to the vitamins supplied, especially by protein supplements of animal origin, and not to the larger amount of protein.

260. Factorial method of estimating requirements.—A method sometimes used in studying the protein requirements for growth is to determine the amounts of protein stored daily in the bodies of growing animals. From what limited data are available, it is then estimated that the animals should utilize the digestible protein in their feed with a certain percentage of efficiency. On this basis, amounts of digestible protein are computed, which, it is believed, should produce normal growth.

Based upon this method, Mitchell and associates of the Illinois Station have recommended amounts of protein for growing animals which are much lower than are commonly fed.[1] This seems to be an unsafe method of estimating requirements. In New York experiments with fattening lambs and with growing dairy heifers, much more protein was actually needed for satisfactory results than had been recommended from the use of this method.[2]

LEGUME FORAGE IS UNEXCELLED FOR GROWING STOCK

Shorthorn cattle on clover pasture. An abundance of good legume forage is excellent insurance against any deficiency of protein, of calcium, or of vitamins for calves, lambs, or foals.

261. Total digestible nutrients or net energy.—For normal growth the ration must supply much more total digestible nutrients or net energy than needed for mere maintenance. This is because an animal can use for growth only the amounts of nutrients left after its maintenance needs have been met. Young animals therefore need more liberal rations than for maintenance, and also generally rations that are more concentrated.

It has been pointed out in the previous chapter that mature cattle, sheep,

and horses can be maintained largely or entirely on roughage, even that which is rather inferior. On the other hand, very young calves, lambs, and foals cannot make good growth on roughage alone, even if it is of high quality. If a young animal does not receive sufficient total digestible nutrients or net energy, its rate of growth will be slow and it may be permanently stunted in size if the underfeeding is continued too long.

262. Stunting of young female animals.—Under practical conditions young female animals are apt to be stunted in size unless they receive sufficient feed to make normal growth up to the time they bear their first young. If they are undersized at this time, they will usually get no opportunity to make up for the lost growth. In milk production there are heavy demands on their bodies for nutrients, and these demands take precedence over any use of nutrients for continued growth of the mother. Because of repeated reproductions and lactations, the animals are unable to complete their growth, and they therefore never reach normal size.

This is especially apt to occur with dairy heifers that have not made normal development by the time of first freshening. Because of the large amount of milk a good heifer produces, she will not be able to make much growth while in milk, unless she is fed with considerable liberality. In many a herd the cows are under-sized and lack high productive capacity, largely because the owner has fed his heifers too scantily.

263. Mineral requirements.—The great importance for growing animals of an ample supply of minerals, especially calcium and phosphorus, has been shown in Chapter VI. A lack of minerals may be even more serious to a young animal than a lack of protein or a lack of total digestible nutrients. Thus, a deficiency of calcium or phosphorus may permanently cripple or deform the animal. Also, the bones may be so fragile that they will readily break in later life. Wherever there is a possibility that the rations for young stock may be lacking in either of these minerals, a mineral supplement should be supplied, as has been previously advised.

There is a heavy drain on the store of calcium and phosphorus in the body during high milk production. It is therefore important to feed dairy heifers and other female breeding animals so that they will start their first lactation with a good store of these minerals.

For calves, lambs, and foals the best insurance against a lack of calcium is to feed sufficient legume hay throughout winter and to provide good pasture during the growing season. Well-cured legume hay not only has an abundance of calcium, but also sun-cured hay is the best source among common feeds of vitamin D, which animals must have in order to utilize the calcium and phosphorus in their rations.

Whenever there is any possibility that the rations for young stock may be lacking in phosphorus, a safe phosphorus supplement should be added, as advised in Chapter VI and also in Part III, where recommendations are made for each class of stock.

In the case of suckling pigs not on pasture, there may be disaster from anemia caused by lack of iron and copper, unless the precautions are taken which are recommended in Chapter XXXIV. In districts where there is a definite deficiency of iodine, it is wise to supply this mineral in the form of iodized salt, or by other means. In certain areas it is necessary to furnish certain trace minerals, as explained in Chapter VI.

264. Vitamin requirements.—In the discussions of the vitamins in Chapter VII, it has been emphasized that it is just as necessary that growing animals receive an adequate supply of vitamins as that they get ample protein and minerals.

Suckling animals will receive plenty of vitamin A in the milk if their mothers are fed suitable rations. On the other hand, if the mothers have been fed rations lacking vitamin A value, the milk may be so low in the vitamin that the young will suffer severely.

When young animals are weaned, care must be taken that sufficient vitamin A value is furnished by feeds rich in carotene, such as well-cured hay, silage, good pasture or other green feed, or by yellow corn. In the case of calves changed from whole milk to skimmilk or milk substitutes at an early age, it is especially important that they be furnished with choice, green-colored hay as soon as they will eat it, to provide both vitamin A and vitamin D.

Young stock on pasture will ordinarily not suffer from a lack of vitamin D, because of the effect of the ultraviolet rays in sunlight. Under winter conditions, however, young pigs are often severely crippled or even paralyzed by rickets, caused by a lack of this vitamin. Also, dairy calves and foals sometimes suffer from rickets. These conditions can usually be entirely prevented by the use of good-quality field-cured legume hay, as described in the chapters of Part III. Beef calves and lambs rarely have rickets, because they are outdoors in the sunlight more, even in winter.

It is shown in Chapter VII and in the swine and poultry chapters that some rations for poultry and also for pigs not on pasture are improved decidedly by the addition of certain B-complex vitamins, especially vitamin B_{12}. Poultry have especially high requirements for riboflavin, and therefore a riboflavin supplement is commonly needed, unless the birds are on excellent pasture.

Information is given in Part III concerning the vitamin requirements of the various kinds of young stock. The amounts of carotene required, except for poultry, are shown in the feeding standards in Appendix Table III, and the vitamin requirements of poultry are stated in Chapter XXXVI.

265. Utilization of food by young animals.—It is well known that young animals make decidedly more rapid gains, considering their size, than do older animals, even when the latter are fed liberal fattening rations. For example, a month-old calf fed liberally on milk will gain about 1 lb. a day per 100 lbs. live weight, while a daily gain of 0.3 lb. per 100 lbs. of weight is large for a 2-year-old fattening steer.

Young animals can build into their protein tissues and skeleton a large part of the protein and mineral matter in their rations. Up to a month of age calves may store 70 per cent or more of the protein, calcium, and phosphorus contained in the milk they consume. As they grow older, the percentages of these nutrients which are stored decrease. Thus, 2-year-old fattening steers will store only about 13 per cent of the total protein in their ration. After growth is completed, but little storage of protein or mineral matter can take place, for the skeleton, the muscles, and the internal organs have reached full development.

Numerous feeding experiments, which are reviewed in Part III, have shown that young animals require considerably less feed per 100 lbs. of gain in body weight and therefore make much cheaper gains than animals which are older. For example, growing and fattening pigs require for each pound of gain in live weight about one-third more feed between the weights of 200 and 250 lbs. than they do between the weights of 50 and 100 lbs. Similarly, the feed cost per pound of gain in weight is about one-third greater in fattening 2-year-old cattle for market than in fattening calves.

There are the following reasons for the more rapid gains and the more economical meat production of young animals:

(1) Their gains are more watery than those of older animals, and also contain more protein and less fat, which has a decidedly higher energy value than protein. More net energy is therefore required to make a pound of gain on a mature fattening animal than on one which is young and growing.

(2) The food eaten by young animals is ordinarily lower in fiber, and hence more digestible and higher in net energy, than that eaten by older animals.

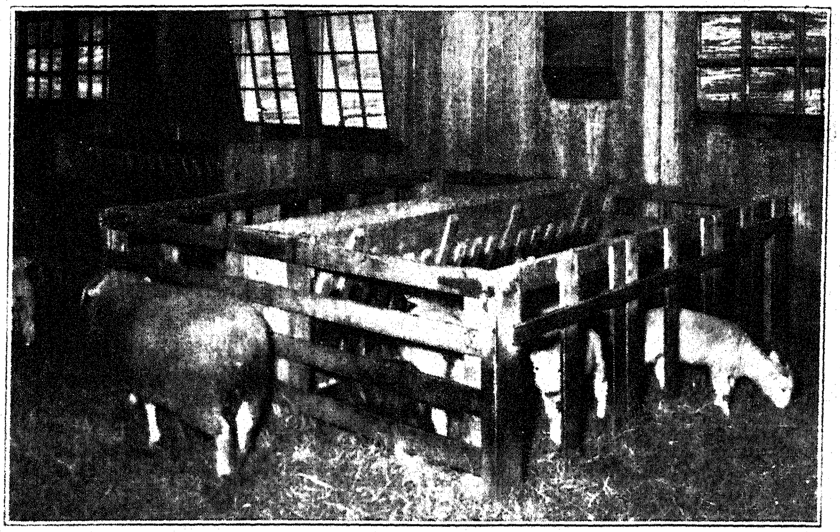
(3) Since young animals eat more feed in proportion to live weight, they

have left for building into body tissues a much larger part of their feed, after their maintenance requirements have been met.

These factors account fully for the cheaper gains of young animals. Contrary to common popular opinion, there is no evidence that a young animal makes any better utilization of the net energy supplied in the feed than an older one, after the maintenance requirements are deducted.

gains during the following pasture season.

The rate of growth and the efficiency with which the nutrients are utilized depend not only on the adequacy of the ration, but also on the inherited growth capacity of the animal. By skillful breeding, much improvement can be made in the efficiency with which farm animals transform food into body tissue. An excellent illustration of such possibilities is the improvement of swine in



LIBERAL FEEDING IS NECESSARY FOR RAPID GROWTH

In addition to their mothers' milk, these early-spring lambs are being supplied with a mixture of grain and other concentrates in a lamb creep, so they will make rapid growth. (From J. P. Willman, Cornell University.)

Denmark, which is mentioned in Chapter XXXIV. Through careful selection of breeding stock, based on feeding and slaughter tests of the progeny, the amount of feed required per 100 lbs. gain has been materially reduced and the quality of the carcasses also decidedly improved.

266. Importance of utilizing growth capacity.—Young animals should always be provided with ample protein, minerals, and vitamins, so as to utilize their great growth capacity in making efficient gains. Except in some types of beef production, it is generally most profitable to supply young animals continuously with sufficient total digestible nutrients to keep them growing normally. Under range conditions, as is shown in Chapter XXIX, it may be most economical to winter beef calves or yearlings on only enough feed to keep them thrifty, without making rapid gains. (284) This is because they then may make very cheap

267. Storage of protein in mature animals.—After an animal reaches mature size, very little storage of protein can occur, since the muscles and other protein tissues are fully developed. If an animal is healthy but has poor muscular development, the size of the muscles can be increased somewhat by suitable exercise and food. Also, an animal

whose muscles have wasted away through sickness or starvation will rapidly repair its tissues upon a return to favorable conditions, thereby storing protein. In addition, if an animal which has been on a low-protein ration is later fed ample protein, a small amount of protein can be stored through increasing the protein reserve in the blood and tissues. (241)

A small amount of protein is stored in the continual growth of such external protein parts as hair, wool, feathers, and hoofs. In the case of a mature animal that is being fattened, a small amount of protein is stored in the fatty tissues.

268. Rates of growth.—The different kinds of farm animals have rates of growth which are characteristic for the species. Also, the various breeds of the same species differ to some extent in mature size that is reached and in the earliness of maturity. Data showing the normal weights and heights of young stock at various ages, such as are presented in Chapter XXVII for dairy cattle and in Chapter XXXIII for horses, serve as convenient guides in determining whether stock have made normal growth.

Studies by Brody and associates at the Missouri Station, as well as investigations by others, have shown that the rate of growth by farm animals generally increases up to the age of puberty, or sexual development.[3] After this, the rate gradually decreases as maturity is approached.

These studies also show that in proportion to their mature size and the length of time taken to reach it, the rates of growth of most species of animals have great similarity. However, the rate of growth in man differs in a striking manner from the rates for farm animals, humans having a much longer juvenile period in proportion to their average length of life.

The various parts of the body develop at unequal rates. The skeleton and head make more rapid early growth than the muscles, and fattening is most rapid at later stages.[4] By greater or less liberality of feeding at various ages it may therefore be possible to change the form and composition of the body somewhat. (283)

The rate of growth and the size of the body are controlled by a hormone produced by the pituitary gland. (54) If an insufficient amount of the hormone is secreted, the animal will be dwarfed. On the other hand, an excessive secretion of the hormone results in a giant animal that is weak physically.

The development of the body may also be affected by the amount of thyroxine, the hormone produced by the thyroid gland, which controls the rate of metabolism in the body. Growth is checked and an animal becomes fatter than usual if normal secretion of thyroxine is prevented by certain drugs. The effect of thiouracil, such a drug, upon pigs is discussed in Chapter XXXIV.

269. Milk the natural food for young mammals.—Milk is practically indispensable for young mammals during the earliest stages of growth, and it is unexcelled as a food during the entire suckling period. Whole milk, containing the fat, has the following nutritive virtues:

(1) It is easily digested and assimilated and has a very high nutritive value per pound of dry matter; (2) it has an abundance of high-quality protein; (3) it is rich in calcium and phosphorus; (4) it provides plenty of energy in the fat and milk sugar; (5) it is high in vitamin A value, if produced by animals fed good rations; (6) it is rich in riboflavin and is a good source of niacin, vitamin B_{12} and other B-complex vitamins; (7) the milk sugar tends to increase the assimilation of calcium and phosphorus and to prevent putrefaction in the digestive tract.

As has been shown in Chapter VIII, milk is not a perfect food for exclusive feeding to animals over long periods. It has but little iron; the content of vitamin D is rather low; and it is not rich in ascorbic acid. In livestock feeding the lack of iron is important only in the case of young pigs not on pasture, as explained previously. The relatively low content of vitamin D can readily be

made good by allowing the young animals access to sunlight, or by including in the ration well-cured legume hay or some other source of vitamin D. The fact that milk has but little ascorbic acid is not of importance in feeding farm animals.

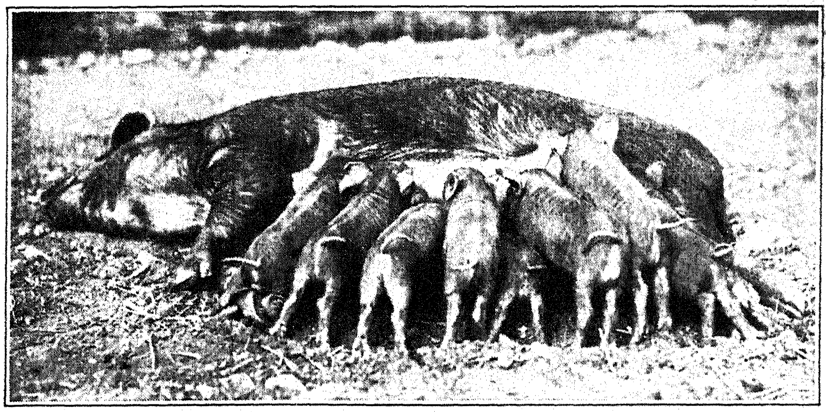
A very young animal has only a limited ability to digest and assimilate fat. If it is fed milk containing a much greater percentage of fat than is normal for that species, serious digestive disturbances may result. Since human milk has less fat than cow's milk, this fact must be borne in mind in feeding very young infants. For delicate infants, cow's milk too high in fat may produce unsatisfactory results.

Even for very young calves, particularly those that are not vigorous, it is best to use milk that is not too rich in fat.[5] Thus, in a Jersey or Guernsey herd it is wise to use milk from a low-testing cow for a week or two, or to add warm skimmilk or even water to lower the fat.

270. Importance of colostrum.—Colostrum, the milk yielded by the mother for a short time after birth, differs greatly in composition from ordinary milk, and it has very important functions. The most indispensable of these is to supply antibodies to protect the new-born animal against certain diseases, especially of the digestive system. Because of this, calves, lambs, foals, or pigs that do not secure colostrum are apt to die from the lack of it.

Colostrum is very rich in protein, cow's colostrum having as much as 17 per cent. A large part of the protein consists of globulins, which are present only in traces in ordinary milk. The antibodies, which are so important for the new-born animal, accompany these globulins. At birth, the blood of the young animal contains practically no antibodies, though they are present in the blood of the mother. For a short time after birth, the globulins, carrying the antibodies, can pass through the intestinal wall and enter the blood stream. However, in a day or two the intestine becomes impermeable to the globulins. The new-born therefore needs colostrum before this occurs. Later in life, the young animal itself develops more or less immunity to digestive infections.

Colostrum is also much richer than ordinary milk in vitamins, especially vitamin A, and in minerals. The high content of vitamin A is of great importance to animals at birth, for they are



MILK IS THE NATURAL FOOD FOR YOUNG MAMMALS

A study of the composition of milk shows that young animals should have rations which provide: (1) A liberal amount of easily-digested nutrients; (2) an abundance of protein of high quality; (3) plenty of minerals, especially calcium and phosphorus; and (4) an adequate supply of vitamins. (From Wisconsin Station.)

born with only a very small amount of it in their bodies.[6] Because of the richness of colostrum in vitamin A, a calf may receive in the first day as much of the vitamin as it would secure in several days from normal milk.

If a calf or other new-born animal cannot receive colostrum from its dam or a similar female, it should get supplements furnishing vitamin A and other vitamins, and it may be necessary to supply antibodies by the hypodermic injection of blood serum from the same species.

By adding a concentrated vitamin A supplement to a good ration for dairy cows for some weeks before calving, the vitamin A value of the colostrum and also the store in the body of the calf can be considerably increased.[7] However, pasture may sometimes not raise the vitamin A value above that of colostrum produced on a good winter ration.[8] If cows have been continuously fed a ration deficient in carotene, their colostrum and their later milk will be low in vitamin A and carotene.

II. Fattening

271. The object of fattening.—We all know that the lean meat from a well-fattened animal is better flavored and more juicy than that from a lean one. This improvement in the quality of the lean meat, and not the storage of thick masses of fat, is the main object in fattening animals before they are slaughtered for meat.

To some extent during growth and especially during fattening, fat is stored in the lean-meat tissues, chiefly between the bundles of fibers of which the muscles are composed. This storage of fat, which forms the so-called "marbling" of meat, adds to the juiciness and flavor, besides increasing the digestibility and nutritive value. During fattening there is also some increase in soluble material of the muscles, which adds to the flavor of the meat.

It has been commonly believed that the lean meat from a well-fattened animal is more tender than from a lean one of the same age. Recent experiments indicate, however, that in the case of young animals of some kinds fattening may not make the lean meat appreciably more tender, though it does greatly improve the juiciness and flavor. Fattening beef cattle generally makes the lean meat somewhat more tender, the effect being more pronounced in older animals. Fattening may not increase the tenderness of lamb or pork.

Beef becomes decidedly more tender, as well as better-flavored, when it is aged for a few days at the proper temperature in a cooler. This is also the case with mutton from older sheep. The increase in tenderness is due to enzyme action on the tough and resistant protein in the connective tissue of the meat. Unless a carcass has a sufficient covering of external fat, it will tend to spoil before it has been sufficiently aged.

272. What fattening is.—In the fattening of mature animals or those which have nearly completed their growth, the gain consists primarily of fatty tissue. In the case of such animals there is but little storage of protein and mineral matter. For example, the gains made by steers which are fattened when nearly full grown will be about two-thirds fat, and will have only about 8 per cent protein, less than 2 per cent mineral matter, and somewhat over 20 per cent water.[9]

Most of the animals raised for meat in this country are now fattened for market at relatively young ages. For instance, but few steers are older than 3 years when slaughtered, and a large proportion are only 1 to 2 years old. Likewise, practically all the lambs not retained for breeding are fattened and marketed before they are a year old. Most of the pigs reach the market when much less than a year of age. Since such animals are still growing rapidly in muscle and skeleton while they are being fattened, the proportion of protein and mineral matter will be much higher in their gains than in those of older animals.

This is shown by Missouri experiments in which analyses were made of the entire carcasses of steers slaughtered before fattening and at various degrees of fatness, to find the composition of the

gain made during fattening.[10] The 500 lbs. of gain made in fattening thrifty 740-lb. steers until they weighed about 1,250 lbs. contained 46 per cent of fat, 12 per cent of protein, and 40 per cent of water.

When steers were made excessively fat by putting on a second 500 lbs. of gain, this additional gain had 68 per cent of fat, less than 7 per cent of protein, and only 22 per cent of water. It was therefore nearly all fatty tissue, with but little lean meat and a low water content.

The fact that the proportion of fat in the gain made by an animal steadily increases during the fattening period is of much practical importance. It is the chief reason why the feed cost per pound of gain increases rapidly after an animal has become fairly well fattened. Such flesh contains much more fat and less water, and it is correspondingly more expensive to produce.

Also, when an animal has become fairly fat, it eats less feed per 1,000 lbs. live weight. Consequently, it has less nutrients left for meat production after the maintenance requirements have been met. In addition, the actual maintenance requirements of a fat animal per 1,000 lbs. live weight may be higher than for one in moderate flesh. (239)

For these reasons, one should have the demands of the market very definitely in mind in fattening stock for market. The animals should be fattened sufficiently to produce the best net returns, considering the probable sale price for animals of various degrees of fatness. However, they should not be made fatter than necessary, or the high cost of the gains will generally reduce the profits.

273. Wastefulness of excessive fattening.—Not only are the gains very expensive when animals are carried to extreme fatness, but also the carcasses do not meet the desires of most consumers. The lean meat, will, it is true, be of the highest quality. However, too large a proportion of the various cuts will consist of masses of fat that are not usually eaten, especially in the case of beef and mutton.

Any excess fat beyond that which is required to make beef or mutton attractive, juicy, and well-flavored is therefore largely waste, though it has been a heavy expense to the producer. Years ago, when cattle were usually fattened after they were well grown, it was necessary to carry them to a high finish to make the meat tender and juicy. Now, however, with our changed methods of beef production in which cattle are fattened while yet young and growing, such extreme fattening is no longer needed to produce beef of good quality.

274. Composition of steers of different ages.—For several years Haecker of the Minnesota Station conducted extensive investigations on the food requirements of steers of different ages, in which the entire carcasses of many animals were analyzed.[11] The table on the next page shows the average composition of the steers at various stages of growth.

The table shows that the percentage of water steadily decreases as the animal matures, falling from over 71 per cent in the calves to 43 per cent in the 1,500-lb. steer. The percentage of fat increases rapidly during the growth and fattening of the animal, increasing from 4.0 per cent soon after birth to over 37 per cent in the 1,500-lb. steer. The protein and ash show less change than the water and fat, but the percentages decrease gradually as the animals grow older.

Haecker found that the storage of protein by the animal, which is rapid in early life, shows a marked slowing up when the animal reaches a weight of about 800 lbs. On the other hand, the gain in fat is most rapid after the steer reaches a weight of 600 lbs.

275. Formation of body fat.—Numerous experiments have shown that after enough nutrients have been supplied to maintain the body, any excess—no matter whether of fat, carbohydrates, or protein—may be transformed into body fat. In the fattening of farm animals most of the fat is undoubtedly formed from carbohydrates, for these are the most abundant nutrients in all common rations. When more protein is furnished than is needed for the repair of the body

tissues, the remainder may, after the nitrogen is split off, likewise be changed into body fat. The fat in the food can also be made into body fat, after more or less change.

The relative values of different feeds for the formation of body fat depend on the amounts of net energy or of total digestible nutrients that they furnish. For this reason, such a feed as corn grain is unexcelled for the fattening of stock.

fat in feeds also affects the character of the milk fat produced by cows. On the other hand, the character of the body fat formed by ruminants (including cattle, sheep, and goats) is apparently not changed appreciably by the kind of fat in the feed.[12]

277. Nutrient requirements for fattening.—The first requirement of a ration for fattening animals is an abundance of total digestible nutrients or net energy. The amount of protein needed

Average composition of steers at various stages *

Normal weight	No. of steers	Water	Dry matter	Protein	Fat	Ash
Lbs.		Per cent	Per cent	Per cent	Per cent	Per cent
100	5	71.84	28.16	19.89	4.00	4.26
200	4	70.43	29.57	19.14	6.01	4.42
300	4	65.72	34.26	18.77	11.19	4.30
400	5	65.79	34.21	19.31	10.56	4.34
500	5	62.90	37.10	19.15	13.73	4.22
600	3	61.20	38.80	19.40	15.04	4.36
700	4	60.35	39.65	18.60	16.58	4.48
800	3	58.44	41.56	18.80	18.52	4.24
900	3	54.10	45.90	17.66	24.08	4.16
1,000	4	52.03	47.97	17.11	26.91	3.95
1,100	3	47.77	52.23	16.38	32.03	3.82
1,200	3	47.96	52.04	16.02	32.32	3.70
1,300	2	47.93	52.07	15.79	32.50	3.78
1,400	1	47.76	52.24	16.15	32.58	3.51
1,500	1	43.48	56.52	15.72	37.59	3.21

* Not including contents of the digestive tract.

276. Effect of food fat on body fat.—At least in the case of swine and chickens, if the feed contains considerable fat the kind of fat in the food may have a pronounced effect upon the character of fat stored in the body. This is because the fatty acids in the food fats are to some extent deposited unchanged in the fatty tissues. If the feed contains considerable fat that is liquid at ordinary temperatures, the body fat may become so soft as to injure the quality of the carcass.

Thus, if swine are fed any considerable amounts of soybeans or peanuts, the pork will be so soft that the carcasses will be undesirable from the market standpoint. Just opposite in effect, cottonseed meal and coconut oil meal tend to produce hard pork. The kind of

and also of vitamins and minerals will depend chiefly on the age of the animals, the requirements being much greater for young animals than for those that are well grown when fattening begins.

The nutritive requirements for fattening each class of stock are discussed in the chapters of Part III, and many practical rations are recommended there and in Appendix Table VII which are adapted to the conditions in various districts. The amounts of nutrients advised for fattening the different classes of stock and at various ages are stated in the Morrison feeding standards.

278. Total digestible nutrients or net energy.—It has already been emphasized that fattening animals need an abundance of total digestible nutrients or net energy. Unless they have a large

surplus of nutrients after their maintenance needs have been met, the rapid formation of fatty tissues is impossible.

The supply of total digestible nutrients must be considerably more liberal for fattening than for normal growth. Thus, a beef calf, after weaning, will make satisfactory growth during winter on good roughage alone. On the other hand, a calf being fattened for baby beef needs a large amount of grain and other concentrates, in addition to good roughage. In fattening young animals it is especially necessary that they be fed liberally. Otherwise, they may merely continue to grow, because of their strong growth impulse, and may fail to fatten properly.

It has been explained in Chapter IV that animals digest and utilize a slightly smaller percentage of the nutrients in the ration when they are given liberal rations than when their feed is limited. (**101**) However, in the fattening of stock this difference is generally more than offset by other factors.

The animal that is fed liberally will have a much larger proportion of the total nutrients in its ration available for fattening, after the amount needed for maintenance is deducted. Less feed is therefore commonly required per 100 lbs. of gain when an animal is fed with sufficient liberality to produce good gain than when the feed supply is so scanty that slow gains result. Also, slow gains greatly prolong the fattening period, and so increase the cost of labor and the other expenses.

FATTENING STOCK NEED A LIBERAL SUPPLY OF CONCENTRATES

Hereford cattle being fattened on an Iowa farm. The first requirement of a ration for fattening animals is an abundance of total digestible nutrients or net energy. These steers are being fed a liberal amount of corn.

Especial consideration is given in Part III to the amounts of grain or other concentrates required for fattening the various classes of stock. Whether or not it will be most profitable to feed fattening cattle or lambs all the grain they will eat will depend first of all on the relative prices of grain and roughage. It will also depend on the amount of premium paid in the market for well-fattened animals. This important problem is discussed in detail in Chapters XXVIII and XXXI.

279. Protein requirements for fattening.—It has been pointed out previously that most of the animals raised for meat in this country are now fattened

for market when relatively young. Such animals are making rapid growth of muscles and other protein tissues, and therefore they need an abundant supply of protein.

In the fattening of mature animals there is but little storage of protein in the gain produced. Much less protein is therefore needed than for growing animals. Indeed, experiments have shown that mature fattening animals will make fairly satisfactory gains on rations supplying only 0.75 to 1.5 lbs. of digestible protein daily per 1,000 lbs. live weight.[13] However, it is probably not advisable in the practical fattening of mature animals to reduce the protein supply to this level.

It has been pointed out in Chapter IV that the digestibility of a ration is considerably reduced if it contains too small a proportion of protein and too large a proportion of carbohydrates and fat. Also, a ration is usually more palatable if it has a reasonable amount of protein, and therefore animals will eat a greater amount of it than of a ration very low in protein. This is important in producing rapid gains.

If fattening animals are fed rations that are rich in carbohydrates and fat, but too low in protein, they are apt to go "off feed" and may even suffer from digestive disturbances. Considering all these factors, it is recommended that even for mature animals a ration for fattening should not generally have a wider nutritive ratio than 1 : 10.0.

280. Mineral and vitamin requirements for fattening.—Mature fattening animals do not require a much greater amount of minerals than they need for mere maintenance, and their vitamin requirements are also low. On the other hand, young fattening animals have even greater needs for minerals and vitamins than those that are merely making normal growth. Particular care must therefore be taken that they have an ample supply of these nutrients, or the gains will be unsatisfactory, and the animals may even become decidedly unthrifty.

For example, the experiments that are reviewed in Chapters XXVIII and XXX show in a striking manner that a lack of calcium may be the chief cause of the poor gains often made by fattening cattle or lambs when there is no legume hay in the ration. As is pointed out there and in Chapter VI, calcium can readily be provided in such forms as ground limestone or ground oyster shell. (157)

281. Factors influencing fattening.—In addition to the suitability and the liberality of the ration, certain other factors have a great influence on the rapidity and economy of gains during fattening.

Unthrifty animals make slow and expensive gains. Young animals that are thin and even somewhat small for their age, due to a previous scanty supply of feed, may make rapid and cheap gains when fed a liberal fattening ration. It will, of course, require considerably longer for them to reach a desired market condition than for animals which are in better flesh at the start of fattening. If young animals have been stunted by a lack of minerals or vitamins, they are apt to be unthrifty and therefore unprofitable in the feed lot.

The ability of an animal to make economical gains and reach a good finish also depends upon temperament. While a wild animal, nervous and active, can be fattened only with extreme difficulty, farm animals are more quiet and usually fatten readily. The restless animal is rarely a good feeder, while the quiet one, which is inclined to "eat and lie down," will usually make rapid gains. This is because the quiet animal has, from a given amount of food, a greater surplus of nutrients available for fat building. Fattening animals must not be allowed to exercise too much, as this wastes nutrients which they might store in their bodies.

III. Studies on Growth and Fattening

282. Effects of nutritional deficiencies on young animals.—Many experiments have been conducted to find the effect of feeding young animals unbalanced rations, which did not supply

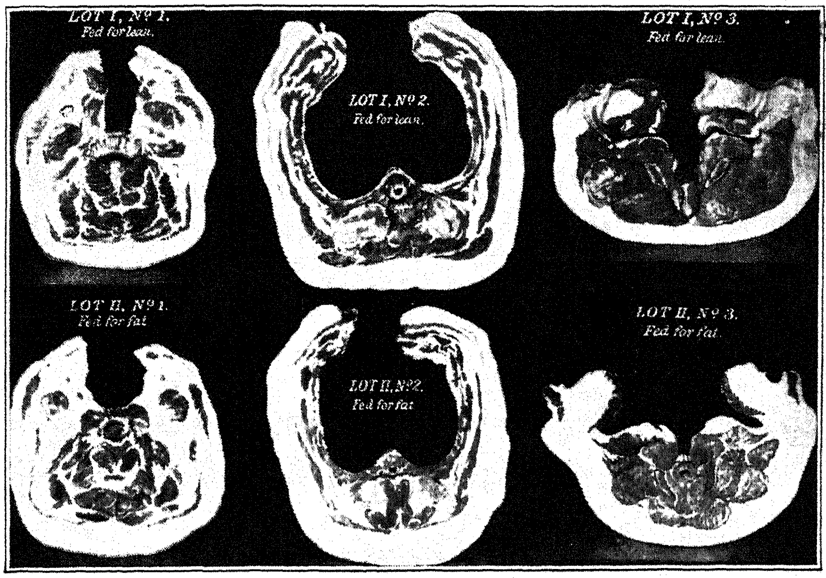
enough protein or which were deficient in minerals or vitamins. These investigations proved clearly that when young animals are fed such rations they are unable to make normal growth.

If the deficiency is too severe or too long continued, disastrous results will be produced. The animals will be permanently stunted or they may be crippled by rickets or other diseases caused by the deficiencies. These experiments were of much practical importance, for they showed clearly the folly of failing to provide proper rations for young animals.

Years ago several experiments were carried on in which pigs that were already fairly well grown were fed corn alone, in comparison with well-balanced rations.[14] Some of these early experiments in animal nutrition were conducted over 65 years ago at the University of Wisconsin by Professor W. A. Henry, the author of the early editions of *Feeds and Feeding.*

In these studies the pigs fed corn alone not only made slow and expensive gains, but also the feeding of corn alone greatly changed the carcasses. The carcasses of pigs thus fed had a wastefully high proportion of fat and much less lean than those of pigs fed balanced rations. Also, the pigs fed corn alone had very weak bones, much smaller livers and other internal organs, and less blood.

It must be remembered that these results were secured with pigs that had already made much of their growth when started on the inadequate ration. If young pigs had been used, those fed corn alone would have made practically no growth or would have died or been permanently crippled or stunted.[15]



PIGS FED CORN ALONE DO NOT DEVELOP NORMAL CARCASSES

Upper row, cross sections of carcasses of pigs fed for lean; i. e., on well-balanced ration, by Henry at the Wisconsin Station. Left, section at shoulder; middle, section between fifth and sixth ribs; right, section at loins. Lower row, carcasses of pigs fed corn alone. Note larger size of muscles of pigs fed well-balanced ration.

To find whether the poor results on corn alone were due to the lack of minerals, Henry conducted 3 experiments at the Wisconsin Station in which well-grown pigs were fed corn alone or corn and mineral supplements.[16] The pigs were confined in pens, with floored exercise

yards, so they could eat no dirt. The pigs fed corn alone soon failed to grow and became unduly fat and dwarfed. Those receiving bone meal or wood ashes in addition grew quite well for a time, but later their gains were poor.

On corn alone 629 lbs. of corn were required for 100 lbs. gain in weight, while only three-fourths as much was required when bone meal or wood ashes was added. Also, the bones of the pigs fed corn alone were only half as strong as those of the others. These trials clearly showed that adding a liberal supply of minerals to the ration was of some benefit, but it did not entirely remedy the deficiencies of corn for growing animals.

In later years numerous trials were carried on to study this matter further. These investigations clearly showed that to make a satisfactory ration for growing pigs, there must be added to corn not only minerals, but also more protein and protein of a kind that will correct the deficiences of the corn protein. For pigs not on pasture, careful attention must be given to meeting the vitamin needs that are discussed in Chapters VII and XXXIV.

283. Influence of methods of feeding upon the carcass.—Interesting experiments, especially those of Hammond and associates at Cambridge University, England, have shown that the proportions of various parts of the body can be modified appreciably by methods of feeding.[17] Also, the proportions of bone, muscle, and fat can be thus changed.

Growth proceeds at different rates in the various parts of the body. The head develops more rapidly at an early age than do other parts, and then the feet and legs grow fast. The trunk, and especially the hindquarters and the loins, are late in developing and are the last parts to reach mature size.

Comparing the different kinds of body tissues, it is found that during early growth the skeleton develops more rapidly than muscles or fatty tissues. However, the muscles develop relatively early, and fat deposition comes last.

In an experiment by McMeekan, working under the direction of Hammond, it was found that the best bacon carcasses were produced when pigs, after weaning, were fed a liberal ration for 16 weeks and then fed a limited ration until they reached market weights.[18] This method of feeding produced a large proportion of lean, apparently because the food supply was abundant during early growth when muscle and bone develop most rapidly.

An opposite method of feeding—a limited ration at first and then full feeding to market weights—produced carcasses that were decidedly of the lard type, with a large proportion of fat and a small proportion of lean. Pigs that were fed a limited ration continuously not only took a much longer time to reach the same market weight, but also they were not sufficiently fattened and they had a poor development of loin and hindquarters. These are the parts of the body which develop last. Pigs which were fed liberally throughout had better bacon carcasses than those which received a limited ration at first.

The amount of feed required per 100 lbs. of gain under various methods of feeding is, of course, fully as important from the practical standpoint as the effect upon the carcass. The effect of the limited feeding of pigs upon the economy of pork production is therefore discussed in some detail in Chapter XXXIV. The data which have thus far been published concerning these English experiments deal only with the effects upon the carcass and not with the economy of production under the various systems of feeding.

284. Effects of scanty feeding of growing animals.—It is now well known that young animals may be permanently injured or even killed by a serious lack of minerals or vitamins. A severe deficiency in amount or quality of protein may also have grave effects. The question then arises as to what the effect will be if young animals are temporarily fed a ration that does not provide enough total digestible nutrients for normal growth, but which has an adequate supply of protein, minerals, and vitamins.

Does such scanty feeding permanently injure or stunt the animal?

This question is of great practical importance, especially in the range districts of the West. Under range conditions young cattle and other stock often get most of their winter feed by grazing the dry grass and other forage on a winter range. The amount of feed available is often scanty, and the digestibility and the net-energy value of such mature and weathered forage is very low. (368) Combined with these lacks, there will be a deficiency of protein, probably of minerals, especially of phosphorus, and often of vitamin A, unless adequate supplements are provided in addition to the weathered forage. As a result of these lacks, young cattle often weigh less in the spring than they did the previous fall. Even under farm conditions, young steers that are to be pastured the next summer are often wintered chiefly on cheap, low-grade roughage and make but little gain in weight.

Extensive experiments were conducted some years ago at the Missouri and Kansas Stations to study the effects of such scanty feeding,[19] and recently similar experiments have been carried on by Winchester and Howe of the United States Department of Agriculture with pairs of identical twin steers.[20] In these recent studies care was taken to provide plenty of protein, minerals, and vitamin A in the scanty rations. Therefore these rations lacked only energy.

The investigations have shown that unless the underfeeding is continued too long, the animals are not permanently stunted but will reach normal size if they are later feed liberally. Steers that had been fed scantily for a time made rapid gains in weight when changed to a liberal ration. During this period of rapid gains they required even less feed per pound of gain than normal. Of course, the steers that were fed scantily for a time and then fed liberally needed a much longer time to reach satisfactory market weight and condition than did the steers fed a liberal ration continuously.

In the recent studies one steer in each pair was fed a liberal ration all the time, while the other steer in the pair was fed from 6 months to about a year of age a scanty ration. This provided from 50 to 75 per cent as much total digestible nutrients as in the liberal ration. On the lowest level of feeding the steers barely maintained their weights for the 6-month period, while the liberally fed steers gained an average of 1.7 lbs. during this time. After about a year of age, all the steers were full-fed until they reached a slaughter weight of 1,000 lbs. It took from 10 to 20 weeks longer for the steers that had been retarded to reach this weight than it did for their liberally fed pair-mates.

Surprisingly, the steers that had been fed scantily for a time required a total of only slightly more total digestible nutrients than their liberally fed mates to reach this weight. Also, the carcass grades and meat quality were not lowered appreciably by the period of scanty feeding.

Differing somewhat from these results, the steers that were scantily fed for a time in the Missouri and Kansas experiments required more total feed to get them ready for market than was needed by others which were fed a normal ration the entire time.

From these studies on scanty feeding and the results of the feeding experiments summarized in Chapter XXIX, we can conclude that feeding young beef cattle so scantily in winter that they make little or no gain is not generally advisable, except in emergencies or when supplemental feeds are very expensive in comparison with summer pasturage.

The purebred livestock breeder who seeks to develop his animals toward an ideal should always be careful to give growing animals ample feed. Detailed information is given in Part III concerning the amounts of feed and especially of concentrates that should be fed to the different kinds of growing animals under various conditions.

285. Continuous growth important. —A California experiment shows that feed may be utilized more efficiently

when young beef cattle on the range are given supplemental feed during periods when the range pasturage is too mature or too scanty to permit normal growth.[21] In the region where the test was conducted, the growth of the range plants takes place from November, after the first rains, until late spring. From June or July the forage is completely dry and mature, and it not only lacks palatability but also is very low in digestible protein. Beef calves grazed on this mature forage without supplemental feed generally lose weight after weaning.

In this experiment it was very profitable to feed steer calves, during the period when the range forage was dried up, a sufficient amount of a protein-rich concentrate mixture to keep them gaining steadily. The feeding of 200 to 300 lbs. of supplemental feed per head at that time saved 500 lbs. of concentrates and 400 to 500 lbs. of hay and other roughage needed later to make up the difference in weight and condition when the cattle were fattened for market.

286. Effect of rate of growth on length of life.—It is generally believed that the length of productive life is longer when an animal receives during growth a fairly liberal, well-balanced ration that permits rapid growth. The extensive experiments by Sherman and associates have been mentioned in the previous chapter, in which rats were fed a liberal ration containing an abundance of high-quality protein, of vitamins, and of calcium, in comparison with a more ordinary ration that produced normal growth. (**245**) The rats fed the superior ration not only grew faster than normal but also remained vigorous for a long time and had a greater length of life than those fed the ordinary ration.

In experiments by McCay and associates rats lived longer when they were raised on a diet that furnished ample protein, minerals, and vitamins, but which supplied so little energy that their growth was greatly retarded.[22] This lengthening of life was, however, due chiefly to a prolongation of the growth period and not to a longer adult life.

It is interesting that the rats which were underfed when young retained the capacity to grow at an age when growth has normally ceased. For example, rats were able to grow after they had been scantily fed to an age of 911 days, which is much more than their normal length of life. When underfeeding was continued as long as this, however, the animals never reached normal size.

Experiments mentioned in Chapter XXVII are being conducted to determine the effect of different levels of feeding of dairy heifers prior to first calving on their subsequent milk production, reproductive performance, and length of useful life.

287. Influence of soil upon breeds of livestock.—It is a common belief among those familiar with the livestock of various countries that the fertility of the soil in any district has a marked effect on the size and ruggedness of a breed of livestock which originates there.

Ashton, who studied this subject in Europe, concluded that the dwarf size of the Brittany breed of cattle in France was due largely to the great deficiency of calcium and phosphorus in the district where the breed was developed.[23] This dwarfed condition is apparently a result of the effect of the deficiencies through successive generations. Perhaps the animals of dwarf size could get along better on feed low in these minerals than animals with large skeletons, and thus survived while others perished.

Ashton concluded that, on the other hand, the large size and rugged frames of the Brown Swiss breed were due in part to the high calcium content of the soil in Switzerland. Also, for generations the cattle have secured their living from roughage, with little or no concentrates. This roughage has undoubtedly supplied a goodly amount of calcium, and of phosphorus as well.

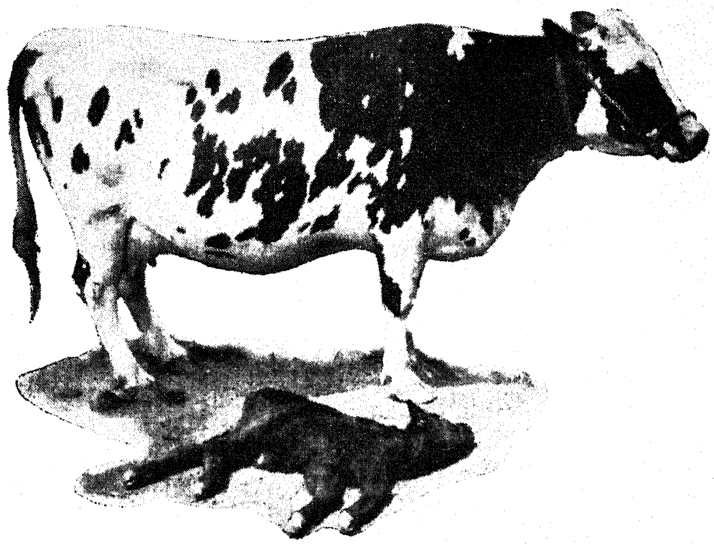
It was also pointed out that in the Island of Jersey the soil is more deficient in calcium and phosphorus than in Guernsey, where the cattle are larger. Breeders of the "Island type" of Jerseys in the United States recognize that there is a tendency for their cattle to become somewhat larger and more rugged in

bone when they are amply fed and kept on soil rich in minerals.

In a study in a good dairy section of New York where the cows were usually fed liberally, Misner determined the size of the cows in many herds and the amounts that were fed of various kinds of roughages.[24] He found that the cows averaged distinctly larger in size on the farms where a high proportion of the roughage was legume hay.

young. Without question, many of the failures in raising young stock are due to faulty nutrition of the breeding females. The sires must also be fed and cared for properly or their fertility will be low.

If the mother is fed inadequately, the offspring are apt to be weak or undersized at birth, and also the supply of milk may be scanty or of low vitamin content. Occasionally, the ration is so deficient that the young are born dead.



NUTRITIVE DEFICIENCIES CAUSE REPRODUCTIVE FAILURE

In Wisconsin experiments cows fed continuously on straw as the only roughage, plus grain and grain by-products, usually produced dead or weak calves. The reproductive failures were due chiefly to deficiencies of vitamin A and calcium. (From Wisconsin Station.)

The small size of the Shetland pony may be due in part to the rigorous climate of the Shetland Islands and the lack of fertility in the soil. In marked contrast are the Percheron, Belgian, Clydesdale, and Shire breeds of horses, all of which were developed in districts where the soil was rich and the climate was moderate.

IV. REPRODUCTION

288. Importance of adequate rations for breeding animals.—It is essential that breeding animals receive rations that fully meet the needs of their own bodies and also supply sufficient amounts of the various nutrients for the unborn

Fortunately, the mother is able to protect the unborn offspring to a certain extent against temporary or small deficiencies in her food by drawing on stores in her own body. Thus, she can draw on her skeleton for calcium and phosphorus and on her muscular tissues for protein. Such maternal protection is, however, at the expense of her own body.

The great differences that occur in reproductive efficiency of livestock is shown by a survey made by Phillips of the number of calves born on various western ranches per 100 cows in the herd at breeding time.[25] The percentage calf crop ranged from 40 to 77 per cent

in different sections of the western range area, with an average of 63 per cent. The calf crops on individual ranches ranged all the way from 25 to 95 per cent. While disease is often a very important factor in reproductive failure, undoubtedly the poor calf crops in some of these herds were due largely to nutritive deficiencies.

On account of the importance of the subject, especial attention is given in the chapters of Part III to the requirements during pregnancy of each kind of breeding stock. Rations, adapted to various parts of the country, are suggested there and in Appendix Table VII that should produce satisfactory results. Information is also given in Part III on the feeding, care, and management of sires of each class of stock. The requirements for egg production by poultry are discussed in Chapter XXXVI.

289. Nutrient requirements of females for reproduction.—It is especially important that the rations of pregnant animals furnish ample amounts of protein, minerals, and vitamins. These nutrients are particularly needed in the development of the unborn young, and deficiencies may produce serious effects.

While it is essential that mature pregnant animals receive a sufficient supply of these nutrients, the requirements during pregnancy are much less than for milk production. Also, most of the growth of the fetus is made during the last third of pregnancy. Until then it is not necessary to give a pregnant animal much more feed than would be needed to keep her in thrifty condition, if unbred. However, more care should be taken to provide sufficient protein, minerals, and vitamins. Pregnancy tends to make animals gain in weight and fatten more rapidly, because it makes them more quiet and also increases the appetite.

It is very important to feed pregnant animals more liberally during the last third of pregnancy. This is necessary to provide for the rapid growth of the fetus at this time and also to get the dam in condition to produce a good flow of milk.

In energy investigations with dairy heifers at the New Hampshire Station, Ritzman found that a month before calving, the amount of energy required by heifers was about 30 per cent higher than in nonpregnant heifers.[26] On the other hand, up to the fourth or fifth month of pregnancy, the energy requirement of pregnant animals was not appreciably higher than for those that were not pregnant.

It is shown later that the milk yield of dairy cows is considerably increased when they are well fed during the dry period. (1082) Also, their calves are more vigorous and the milk is richer in vitamin-A value. Similarly, it is shown in Chapter XXXI that when ewes are insufficiently fed during the last part of pregnancy, they are apt to have weak lambs. Also, they have insufficient milk for the lambs and may show but little motherly instinct.

In general, breeding females should be so fed that they are in thrifty condition. However, they should never be allowed to become too fat, or their breeding efficiency may be seriously decreased. Keeping them for long periods in over-fat, show condition is decidedly detrimental. Abundant exercise is essential for the best results.

It is important that breeding animals be raised well during the growth period. Undernutrition delays sexual development, and also females that have been poorly fed while growing are apt never to reach normal size. After they have their first offspring, the drain on their bodies in milk production prevents further growth unless they are fed liberally. Young pregnant females which have not yet completed their growth should therefore receive sufficient feed so they will be in good condition and of normal size when they have their first young.

290. Protein, minerals, and vitamins.—In comparison with the needs of a non-pregnant female, the requirement for protein during pregnancy is increased more than for total digestible nutrients or net energy. This is because the fetus consists chiefly of protein. The greatest need

for protein comes during the last third of pregnancy, when the growth of the fetus is most rapid.

The protein supply for pregnant animals should not only be sufficient in amount, but also the protein must be of proper quality. No attention need usually be given to the quality of protein in the case of dairy or beef cows, ewes, or mares, for the reasons that have been explained in Chapter V. (**112**) On the other hand, the quality of protein is as important as the amount of protein in feeding brood sows. Investigations with laboratory animals have shown that a lack of protein or a lack of one of the essential amino acids may cause a complete cessation of estrus, or heat periods.[27]

It has been shown in Chapter VI that a deficiency of minerals may cause reproductive disaster. Adequate amounts of calcium and phosphorus are necessary for successful reproduction. Also, attention must be given to the so-called trace elements, including iodine, iron, copper, and cobalt, in the areas where there may be a deficiency of one or more of these minerals.

A liberal supply of vitamin A, usually furnished by carotene, is especially necessary for pregnant animals. As is shown elsewhere, a lack of vitamin A will not only injure the unborn young, but will also cause the mother's milk and even the colostrum to be seriously deficient in the vitamin. (**192**) The vitamin A and carotene requirements of pregnant animals of the various kinds are therefore discussed in detail in Part III. The amounts of carotene advised for breeding females are stated in the Morrison feeding standards. (Appendix Table III.)

The requirements of the various animals for the other vitamins, including vitamins D, E, and C, and the B-complex vitamins, have been discussed in Chapter VII. Further information concerning any special needs by the different classes of stock is given in Part III.

291. Pasture and legume hay important for breeding stock.—Providing breeding stock with good pasture on fertile land during as much of the year as possible is the best insurance against nutritive deficiencies. Cows maintained continuously on well-balanced dry rations do not seem to reproduce so well as those allowed access to pasture.[28] Shy breeding, which develops on winter rations, is often overcome when the cattle have been on good pasture.

It has been mentioned previously that brood sows which are continuously kept in dry lot often have unsatisfactory litters or fail to nourish the pigs well after birth, even when the sows are fed apparently well-balanced rations. (**189**) The best substitute for pasture is alfalfa or other legume hay of first-class quality, but even this is not a complete substitute if the sows are raised in dry lot and continuously kept off pasture.

The importance of giving breeding stock plenty of good roughage, especially legume forage, is shown by the Indiana experiments with ewes which are reviewed in Chapter XXX. The results were unsatisfactory when breeding ewes were wintered on oat straw and corn silage for roughage, even when plenty of protein and mineral supplements were added. The deficiencies were corrected by furnishing excellent-quality alfalfa hay or dried immature grass.

292. Nutrients stored in the fetus.—The actual amounts of nutrients contained in a fetus at birth are not very large. The bodies of young animals at birth are very high in water content, new-born calves containing 71 to 75 per cent water. In Missouri experiments new-born 65-lb. Jersey calves contained about 11.8 lbs. protein, 2.5 lbs. fat, and 2.7 lbs. mineral matter; and 80-lb. Hereford calves, 14.6 lbs. protein, 2.9 lbs. fat, and 3.6 lbs. mineral matter.[29] These are no greater amounts of nutrients than are contained in 400 to 500 lbs. of milk of average composition. To these amounts of nutrients must be added those contained in the fetal membranes and fluids.

These data show why pregnant animals do not require such great amounts of nutrients, even during the last part of pregnancy, as are needed for producing a good yield of milk.

293. Nutritive requirements of sires.—Practical experience shows that sires must be kept in thrifty condition to retain their breeding powers. Care must therefore be taken to make sure that their needs for protein, minerals, and vitamins are met. However, the nutrient requirements for mature sires in ordinary service are not far different from the needs for mere thrifty maintenance. Information is given in Part III on the feeding and care of sires of each class of stock.

It will be noted in the experiments there summarized that a nutritive deficiency, as of vitamin A, usually produces visible symptoms of deficiency in the sire, before it impairs his breeding potency.

Young sires should be fed so that they grow normally and develop vigorous bodies and strong skeletons. They therefore need rations having ample amounts of protein, minerals, and vitamins.

QUESTIONS

1. Why is thrifty growth important in farm animals?
2. Compare the nutritive requirements for growth and for maintenance, considering: (a) Protein; (b) total digestible nutrients; (c) minerals; (d) vitamins.
3. How can the amounts of protein required by growing animals be determined?
4. Which is more serious for a young animal—a moderate deficiency of total digestible nutrients or a lack of an essential mineral or vitamin?
5. How can one be sure that calves, lambs, and foals have plenty of calcium, without feeding a special calcium supplement?
6. Which vitamins are most apt to be lacking in the rations of pigs in winter?
7. Discuss the utilization of food by young animals. Why do young animals produce meat more economically than older ones?
8. What is the relative rate of growth of different parts of the body at various ages?
9. State 7 nutritive virtues of whole milk for young animals.
10. What deficiencies does milk have as an exclusive food over long periods?
11. Why should a very young animal not be fed milk unduly rich in fat?
12. Why is it important that new-born animals receive the colostrum?
13. What is the object of fattening meat animals?
14. Discuss the composition of the gains made during fattening.
15. Why is it generally uneconomical to carry an animal to a greater degree of fatness than is necessary to meet the market demands?
16. From what nutrients may body fat be formed? From what source is most of it usually made by farm animals?
17. What is the effect of food fat upon body fat in swine and in ruminants?
18. Discuss the requirements of fattening animals for the following: (a) Total digestible nutrients or net energy; (b) protein; (c) minerals; (d) vitamins.
19. What factors, other than the ration, influence the rapidity and economy of gains during fattening?
20. What is the effect of feeding young pigs such a ration as corn alone?
21. What method of feeding produced the best bacon carcasses in the English experiments?
22. Of what practical importance are the results of the experiments in which growing animals have been fed scanty rations for a time?
23. What results were secured when beef calves were fed enough supplemental feed, in addition to dried-up range, to keep them growing steadily?
24. What is the effect of nutrition upon length of life of rats?
25. How may the fertility of the soil in a region affect the size of farm animals?
26. Discuss the importance of adequate rations for breeding animals.
27. Compare the nutrient requirements for pregnancy with those for milk production.
28. Discuss the importance of pasture and legume hay for breeding stock.

REFERENCES

1. Mitchell, Ill., Amer. Soc. Anim. Prod., Proc. 1933; Mitchell, Hamilton, and Kammlade, Ill. Rpt. 1932; Blaxter and Mitchell, Jour. Anim. Sci., 7, 1948, pp. 351–372.
2. Willman and Morrison, N.Y. (Cornell) Bul. 691; Willman, Klosterman, and Morrison, N.Y. (Cornell) Bul. 834; Lofgreen, Loosli, and Maynard, N.Y., Jour. Anim. Sci., 10, 1951, pp. 169–183.
3. Brody, Bioenergetics and Growth, 1945; Brody et al., Mo. Res. Buls. 96, 97, 98, 99, 101, 102, 103, 104, 105, 116; see also: Mumford et al., Mo. Res. Bul. 62; Brody and Rags-

dale, Mo. Res. Buls. 67, 80; Hammond, Growth and Development of Mutton Qualities in the Sheep.
4. Hammond, Growth and Development of Mutton Qualities in the Sheep; Hammond, Jour. Roy. Agr. Soc., England, 93, 1932, pp. 1–15.
5. Beach, Conn. (Storrs) Bul. 31; Washburn and Jones, Vt. Bul. 195.
6. Kunerth, Kramer, and Riddell, Kan. Acad. Sci. Trans., 38, 1935, pp. 209–211; Moore and Berry, Md., Jour. Dairy Sci., 27, 1944, pp. 867–873; Satterfield, Clegg, and Holmes, Mass. and N.C., Food Res., 9, 1944, pp. 206–211; Sutton, Kaeser, and Soldner, Ohio, Jour. Dairy Sci., 28, 1945, pp. 933–939; Semb, Baumann, and Steenbock, Wis., Jour. Biol. Chem., 107, 1934, pp. 697–703; Dann, Biochem. Jour., England, 27, 1943, p. 1998.
7. Wise, Caldwell, Atkeson, and Hughes, Kan., Jour. Dairy Sci., 29, 1946, pp. 515–516; Spielman, Thomas, Loosli, Norton, and Turk, N.Y., Jour. Dairy Sci., 29, 1946, pp. 707–715; Spielman, Eaton, Loosli, and Turk, N.Y., Jour. Dairy Sci., 32, 1949, pp. 367–374; Nezvesky et al., Conn., Jour. Dairy Sci., 33, 1950, pp. 315–323.
8. Parrish, Wise, Atkeson, and Hughes, Kan., Jour. Dairy Sci., 32, 1949, pp. 209–221; Henry, Houston, and Kon, Jour. Dairy Res., England, 11, 1940, pp. 1–8; Stewart and McCallum, Jour. Dairy Res., England, 13, 1942, pp. 1–4.
9. Lawes and Gilbert, Jour. Royal Agr. Soc., England, 1860.
10. Trowbridge, Moulton, and Haigh, Mo. Res. Bul. 30; see also: Moulton, Trowbridge, and Haigh, Mo. Res. Bul. 61.
11. Haecker, Minn. Bul. 193.
12. Edwards and Holley, Ga., Amer. Soc. Anim. Prod., Proc. 1939; Helser, Beard, Culbertson, Thomas, and Nelson, Iowa Rpts. 1935, 1936; McCay and Newlin, N.Y. (Cornell) Rpt. 1941.
13. Mitchell, Ill., National Res. Council Bul. 67.
14. Henry, Wis. Rpts. 1886, 1887, 1888, 1889; Duggar, Ala. Bul. 82; Shelton, Kan. Bul. 9; Sanborn, Mo. Buls. 10, 14, 19; Fortier, France, Ext. Trav. Soc. Cent. d'Agr., Dept. Seine-Inf., 1889, 1890; see also: Forbes, Mo. Bul. 81; Grindley et al., Ill. Buls. 168, 169, 171, 173.
15. Hogan, Kan., Jour. Biol. Chem., 29, 1917, pp. 485–493; Reed and Huffman, Mich. Quar. Bul. 6, 1924, No. 4.
16. Henry, Wis. Rpt. 1890, Wis. Bul. 25.
17. Hammond, Growth and Development of Mutton Qualities in the Sheep; Hammond, Farm Animals.
18. McMeekan, Jour. Agr. Science, England, 30, 1940, pp. 276–343, 387–436, 511–569; 31, 1941, 1–49.
19. Waters and Trowbridge, Mo., Soc. Prom. Agr. Sci., Proc. 1908; Trowbridge, Moulton, and Haigh, Mo. Res. Buls. 28, 43; Moulton, Trowbridge, and Haigh. Mo. Res. Buls. 54, 55; Ritchie, Moulton, Trowbridge, and Haigh, Mo. Res. Bul. 59; Hogan, Mo. Res. Bul. 123; Waters, Cochel, and Vestal, Kansas Industrialist, May 10, 1913, Apr. 18, 1914; see also: Ritzman and Benedict, N.H. Tech. Bul. 26; Benedict and Ritzman, N.H., Carnegie Inst. Washington, Publications 324, 377.
20. Winchester and Howe, U.S.D.A. Tech. Bul. 1108.
21. Guilbert, Hart, Wagnon, and Goss, Cal. Bul. 688.
22. McCay, Crowell, and Maynard, N.Y., Jour. Nutr., 10, 1935, pp. 63–79; McCay, Maynard, Sperling, and Barnes, N.Y., Jour. Nutr., 18, 1939, pp. 1–13; see also: Verzar, Switzerland, Helvetica Medica Acta, Sup. 6 to Vol. 7, 1940–41, No. 5–6, pp. 7–15.
23. Ashton, Mo. Res. Bul. 141.
24. Misner, N.Y. (Cornell) Bul. 719.
25. Phillips, U.S.D.A., Yearbook of Agr., 1939, pp. 476–482.
26. Ritzman, N.H. Bul. 319.
27. Guilbert and Goss, Cal., Jour. Nutr., 5, 1932, pp. 251–265; Pearson, Hart and Bohstedt, Wis., Jour. Nutr., 14, 1937, pp. 329–338.
28. Friedman and Turner, U.S.D.A., Yearbook of Agr., 1939, pp. 482–491.
29. Haigh, Moulton, and Trowbridge, Mo. Res. Bul. 38; see also, Yapp, Ill. Rpt. 1932, Yapp, Ill., Amer. Soc. Anim. Prod., Proc. 1931, pp. 133–136.

CHAPTER X

PRODUCTION OF MILK, WORK, AND WOOL

I. Production of Milk

294. The secretion of milk.—For good growth of all young mammals an abundant supply of the mother's milk is necessary under normal conditions. It is therefore essential that we understand the main facts concerning the requirements for the secretion of milk.[1]

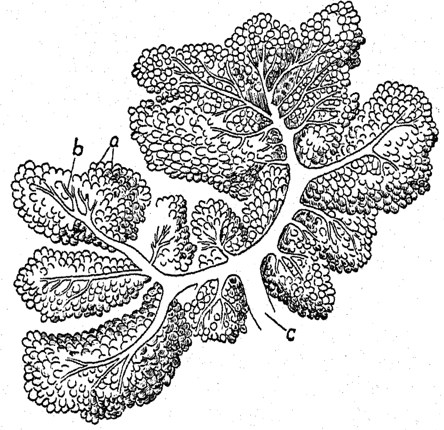
The fully developed mammary gland, in which milk is secreted, consists of a multitude of small, sac-like secreting bodies (called alveoli) and the duct system into which the milk is poured. The alveoli are grouped into clusters, much like bunches of grapes.

The smallest ducts, into which the alveoli secrete the milk, unite to form larger ones. The ducts are not uniform in size throughout their length but are greatly enlarged in places, to provide more storage capacity for the milk as it is secreted. In some animals the large milk ducts open directly on the surface of the teat, but in others, as in cows, they open into a small cavity, called the milk cistern, which is just above the teat.

The amount of milk an animal can produce depends primarily on the amount of secreting tissue in the mammary glands. In good dairy cows, for example, not only is the udder large, but most of it consists of actual secreting tissue.[2] On the other hand, in the udders of beef cows there is much less secreting tissue, and a considerable part of the udder consists of fatty tissue.

When milk is secreted, the blood, laden with nutrients, is brought by the capillaries of the udder to the alveoli. The nutrients then pass through the walls of the capillaries into the lymph and thence into the cells of the alveoli. Here, by one of nature's wonderful processes they are converted into milk, that differs greatly in composition from the blood from which it is made.

Only a very small portion of the nutrients in the blood is removed each time the blood passes through the udder. Therefore the rate of flow of blood is truly remarkable in the case of a high-producing cow. It is estimated that about 400 lbs. of blood flow through the udder for each pound of milk produced.[3] Thus, in the case of a cow yielding 60 lbs. of milk a day, 24,000 lbs. of blood would flow through the udder in a day.



Portion of Mammary Gland of Cow

Small portion of gland, greatly magnified. A, alveoli, in which milk is secreted; b, small milk duct; c, larger milk duct. (After Klein.)

The great number of times the blood makes the circuit from the heart to the udder and back again is evident from the fact that this amount of blood is about 300 times the total amount of blood in the body of a 1,000-lb. cow. The energy required to pump this amount of blood through the udder represents only a small part of the requirements of the cow for milk production. There is therefore no question but that

a good cow is a very hard-working animal.

295. Source of nutrients in milk.—The chief constituents of milk—casein, milk fat, and lactose (milk sugar)—are true secretions of the mammary gland, for they have special properties and are found nowhere else in the body. Certain constituents of milk are transferred direct from the blood, including mineral matter, the vitamins, globulin, and albumin.

Investigators have endeavored to determine the exact blood source of the various nutrients in milk.[4] One method has been to analyze samples of blood taken from an artery of a cow before it passes through the udder and of blood from a vein after passage through the udder. In some of the studies various nutrients labeled with radio-isotopes have been used in order to trace the origin of the milk constituents.

The experiments indicate that casein is made chiefly from amino acids taken up from the blood. Some synthesis of certain amino acids for making the casein may occur in the mammary gland. The milk fat is mostly derived from the fat of the blood. In the case of ruminants, but not in non-ruminants, the simpler fatty acids may be formed from acetic acid produced in the bacterial carbohydrate digestion in the rumen. The lactose is formed principally from blood glucose.

296. When is milk secreted?—Investigations have shown that milk secretion is a continuous process and that most of the milk obtained at a milking is already present in the udder when milking begins.[5] For example, when cows have been slaughtered just before the normal milking time and their udders removed, the udders have contained nearly as much milk as was secured at the previous milking.

The rate of secretion is probably most rapid for a time after milking is completed, for there is then little or no pressure in the udder. As the milk gradually accumulates in the milk ducts before the time of the next milking, the rate of secretion tends to slow up, due to the increasing pressure. When the pressure becomes great enough, secretion entirely ceases. This is why cows can be dried off by abrupt stopping of milking. (**1081**)

297. "Letting down" and "holding up" of milk.—The secretion of milk is involuntary and cannot be prevented by the animal, any more than can breathing or the circulation of the blood. The yield may, however, be reduced considerably through nervousness caused by fright or unusual conditions.

It is explained in Chapter XXVI that if the proper stimulus occurs at milking time, the milk is forced out of the alveoli and small ducts of the udder by the action of a hormone produced in the pituitary gland at the base of the brain. (**1093**) We then say that the cow has "let down" her milk.

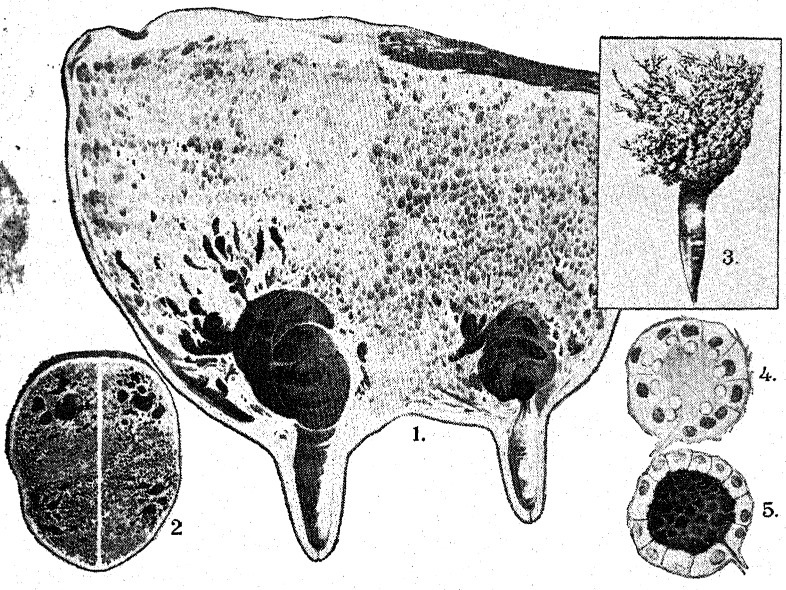
If she does not receive the proper stimulus, this hormone is not secreted, and we say that she "holds up" her milk, because it is not forced out of the alveoli and ducts. More milk is secured by rapid milking than by slow milking, because the effect of the hormone lasts only a short time.

These studies provide an interesting explanation for the well-known fact that regularity in feeding and stable management is necessary to secure the largest yields from good cows. Also, the kind milker who gains the confidence of cows secures more milk from them than a rough or indifferent person.

298. Development of the mammary glands.—The mammary glands of a young female are only slightly developed before sexual maturity, but then develop through the action of certain hormones.[1] For example, in the case of dairy calves, the milk ducts leading out from the milk cistern are small and short, with few branches. After sexual maturity is reached and the animal comes in heat, the duct system begins to grow and branch out into the fatty pad of tissue which at that time composes most of the udder. This growth is caused by a hormone which is secreted in the ovaries and carried in the blood to the udder. This hormone, usually called *estrogen*,

or *estradiol,* is the same hormone that causes the heat period in females. With the successive heat periods, further growth of the duct system occurs.

If the animal does not become pregnant, the duct system becomes fairly extensive, but there is not much development of the alveoli, which are the secreting tissues. When pregnancy occurs, a further growth takes place in the duct system, and also the alveoli develop rapidly. This is caused by estrogen and also by a hormone secreted by the corpus luteum, or "yellow body," in the ovary of the pregnant animal. This hormone is usually called *progesterone.* Hormones produced by the pituitary gland also seem to be concerned with the growth and development of the mammary glands.



STRUCTURE OF THE COW'S UDDER

1. Longitudinal section through one side of udder and teats of cow. The narrow duct at the end of the teat, or the teat canal, may be seen, also the cavity in the teat, and the milk cistern. Although there is no septum, or visible division, between the fore and hind quarters, no communication exists between the milk ducts in the two quarters. In this section the tissue of the fore quarter is colored slightly lighter than that of the hind quarter.

2. Horizonal section of the four quarters of the cow's udder. The septum, or division, between the right and left halves of the udder is clearly visible. Note the size and distribution of the milk ducts.

3. Milk cistern and milk ducts of a fore quarter of udder.

4. Cross-section of an alveolus before milking. The droplets of fat, indicated in the figure by the light-colored spots in the cells, are discharged into the cavity of the alveolus through the cell walls when milk is secreted.

5. Cross-section of an alveolus after milking. This should be contrasted with Figure 4, as it shows the appearance of the cells of the alveolus following secretion. Note that the cells have lost their fat droplets and their fluid to a large degree. (Reproduced from charts by Rubeli, Berne, Switzerland.)

In some animals the growth of the secreting tissue is largely completed during the first half or two-thirds of pregnancy. The cells of the alveoli then begin to secrete a fluid that resembles colostrum, which is the first milk yielded by the mother after the birth of the young. The beginning of secretion is brought

about, not by either of the two hormones that have been mentioned, but by a hormone called *prolactin,* or *lactogen,* which is secreted by the forward, or anterior, part of the pituitary gland.[6]

Because of the rapid enlargement of the udder during the latter part of pregnancy, it was formerly thought that nearly all the growth of the gland takes place at that time. However, much of the increase in size is due to accumulation of secretion in the alveoli and ducts.

The function of the colostrum in protecting the new-born against disease has been explained in the previous chapter. (**270**)

When the milk yield decreases during the latter part of the lactation period and the animal finally "goes dry," the alveoli disappear to some extent and are rebuilt during the next pregnancy period.

Young heifers often develop the habit of sucking each other, and this manipulation of the udder will sometimes start the secretion of milk, even in the unbred animal. In one instance at the Wisconsin Station a barren heifer produced over 5,000 lbs. of milk in 630 days, the maximum daily yield being 18.7 lbs.[7]

Such a milk flow is, however, much less than the animal would produce following pregnancy and the birth of young.

299. Use of hormones to cause milk production.—Experiments have shown that udder development and secretion of normal milk can be produced in non-pregnant females by the hypodermic injection of hormones, or implanting a tablet of the hormone under the skin. This effect is produced not only by natural hormones, but also by certain synthetic compounds, especially diethylstilbestrol.

Experiments have been conducted with heifers and cows that failed to conceive, to find whether treatment with hormones would produce worth-while milk yields.[8] In some cases yields of as much as 431 lbs. of fat in 10 months have been secured, but in other instances the results have been disappointing. The effect has seemed to be more favorable with heifers than with cows.

300. Milk production requires large amounts of nutrients.—Many do not realize fully the large amounts of nutrients that are yielded by an animal producing a good flow of milk, and that must therefore be supplied in her feed. A fair cow yielding annually 8,000 lbs. of milk containing 3.5 per cent fat will produce in her milk each year much more protein and somewhat more energy and minerals than there are in the entire body of a fat 2-year-old steer. In addition, she will have developed the body of her calf.

Unless an animal in milk receives sufficient nutrients to meet her needs, she cannot continue to produce a good yield. During the first part of the lactation period, if the animal is fed insufficiently she will do her best to provide enough milk for her young by drawing nutrients from her body. However, this cannot continue long, and her milk yield will fall to the amount that can be made from the nutrients she receives.

Since milk is especially rich in protein and also in calcium and phosphorus, the ration of an animal producing milk must supply liberal amounts of these nutrients. Also, the protein in the ration must be of satisfactory quality, as has been shown in Chapter V. The large requirements for protein, total digestible nutrients, calcium, and phosphorus for milk production are in strong contrast to the amounts needed by an animal that is merely being maintained, or even by a pregnant animal that is not producing milk.

The quantities of the various nutrients required by any milking animal will depend primarily on the amount of milk that is actually being produced. Thus, a cow yielding 60 lbs. of milk a day will need twice as much nutrients, above her maintenance requirements, as will one producing only 30 lbs. of milk of the same richness. Also, a greater amount of nutrients is required for each pound of rich milk than for milk low in fat percentage.

These simple facts are disregarded by many dairymen, who allow the net returns from their herds to be seriously

reduced because they do not feed the individual cows in proportion to their actual productions. This important matter is discussed in Chapter XXV.

In considering the food requirements for milk production it should be borne in mind that the mammary gland does not receive a particular kind of blood suited to its special needs. It receives the very same kind of blood that flows to the other body tissues, and therefore it must compete with the other organs for its supply of nutrients.

The requirements for milk production by the various farm animals are discussed in detail in the chapters of Part III, and example rations for each class of stock are given in Appendix Table VII. The amounts of nutrients advised for each kind of milking animals are stated in the Morrison feeding standards. (Appendix Table III.)

301. Protein.—Often the milk production of farm animals is lowered by a lack of sufficient protein in the ration. Care should therefore always be taken to provide ample protein. In the case of brood sows, attention must be given to the quality of protein, as well as to the amount. For the reasons explained in Chapter V, the quality of protein in any usual ration for dairy cows, beef cows, ewes, or mares will generally be satisfactory, if good quality roughage is fed. (112, 127) If considerable of the roughage is legume forage, satisfactory quality of protein in the ration is insured.

Protein is used very efficiently in milk production, especially by good dairy cows. This is shown by the fact that fairly good production is secured when cows receive in their feed, in addition to their maintenance requirements, only 1.25 lbs. of digestible protein for each pound of protein in the milk. In the economy with which she converts the protein of feeding stuffs into protein of the highest nutritive value, the dairy cow far excels the other farm animals, as is emphasized in Chapter XII. (351–352)

302. Total digestible nutrients or net energy.—The requirements for total digestible nutrients and net energy in milk production are far greater than the needs for pregnancy, even during the last months, when the growth of the fetus is most rapid. The high need for energy in milk production is shown by the fact that the metabolic rate of the body is so speeded up in producing a good yield of milk that twice as much heat is produced as in animals that are not lactating.[9]

For efficient milk production, dairy cows, beef cows, brood mares, and breeding ewes should, first of all, receive a liberal supply of good-quality roughage. This will not only furnish total digestible nutrients and net energy, but it is also important in providing minerals and vitamins. In addition to roughage, they should receive whatever amounts of concentrates are necessary to maintain a satisfactory flow of milk. Brood sows must get most of their nutrients for milk production from concentrates.

The amount of concentrates required for any class of stock depends on the quality of the roughage they receive and on the amount of milk they are yielding. Thus, beef cows nursing calves need no grain in addition to good pasture, while high-producing dairy cows cannot secure enough nutrients from pasture alone, unless it is most excellent.

303. Fat requirements.—Investigations have shown clearly that the fat in milk can be formed not only from the fat in the feed but also from carbohydrates and even indirectly from protein. For example, in an experiment many years ago by Jordan and associates a cow was fed for over 3 months a ration from which nearly all the fat had been extracted.[10] During the trial she produced 62.9 lbs. of fat in her milk, while there was only 5.7 lbs. of digestible fat in her feed. The rest was made chiefly from carbohydrates, as but relatively little could have come from excess protein in the ration.

In spite of the fact that the fat in milk can be made from other nutrients than fat, a certain minimum amount of fat is needed in the ration for maximum milk yield, at least with high-producing dairy cows and milk goats. Extensive ex-

periments summarized in Chapter XXV showed that when good dairy cows were fed concentrate mixtures having only 2.7 per cent fat, with the usual roughages, they produced 4 per cent less milk than when the ration had more fat. (1020) The difference in yield, which was only small, could be made up by feeding a slightly larger amount of the low-fat concentrate mixtures.

The effect of the low-fat ration may have been due to the less efficient use of energy on a ration very low in fat, which has been mentioned previously. (133) Another possible explanation is that cows are able to make milk fat more readily from food fat, though they can synthesize it from other nutrients.

In these experiments the percentage of fat in the milk was not appreciably reduced on the low-fat rations in the case of dairy cows, but the milk yield was slightly less. However, with milk goats a ration very low in fat tended to decrease the fat content of the milk.

So far as is known, no especial attention need be paid to the fat content of rations for beef cows, ewes of the common breeds, brood mares, and brood sows. This is because their milk yield is not large in comparison with that of high-producing cows or milk goats.

304. Mineral and vitamin requirements.—The mineral and vitamin requirements of farm animals have been discussed at some length in previous chapters. The importance was there emphasized of supplying sufficient calcium, phosphorus, vitamin A, and vitamin D to make possible a high yield of milk, without injury to the animal.

The mineral and vitamin requirements for milk production by the various classes of stock are considered further in Part III, and the influence of the vitamin supply in the ration upon the vitamin content of the milk is discussed later in this chapter.

305. Effect of various factors upon the composition of milk.—The effects of various factors upon the yield and composition of milk have been studied chiefly in experiments with dairy cows. These factors are therefore discussed in detail in Chapter XXV.

In general, there is a strong tendency for a lactating animal to produce milk of normal composition under widely varying conditions. Any inadequacy in the ration or fault in the methods of care and management will generally manifest itself by a reduction in the yield of milk, rather than by a change in its chemical composition. However, certain factors have an effect on the fat percentage. The content of certain trace minerals in milk can be increased by a very liberal amount in the feed. A very important fact is that the vitamin A value of the milk depends on the vitamin A or carotene content of the ration.

306. Effect of feed on protein, fat, and milk sugar of milk.—A deficiency or an excess of protein in the ration does not appreciably change the composition of milk. However, a lack of protein greatly decreases the yield. In Ohio experiments cows fed rations unusually lacking in protein produced a low yield, but the milk did not differ in any important respect from that of cows fed rations rich in protein.[11] Calves and laboratory test animals made equally good growth on the two kinds of milk. The only significant difference was that the milk from the high-protein feeding contained more of the non-protein nitrogenous compounds, including urea, which are found in traces in milk. Also, this milk was slightly higher in the vitamin B complex.

If the ration of a dairy cow does not have a certain minimum amount of fat, the yield of milk will be reduced, as has already been mentioned in this chapter. The experiments reviewed in Chapter XXV show that the richness of the milk may be considerably increased for a few days by adding fat or fat-rich feeds to the ration. The fat content, however, tends to fall back to normal later, even though the feeding of fat is continued. Certain feeds, especially coconut meal and palm-kernel oil meal, may cause a very slight increase in the fat content of milk over a longer period. On the other hand, cod-liver oil and certain other fish

oils decidedly decrease the percentage of fat in the milk of cows.

When fed in considerable amounts, feeds that are rich in fat may have a marked effect on the character of the fat in milk, just as they do upon the body fat produced by swine. Thus, soybeans and peanuts tend to produce soft butter, while cottonseed meal and coconut oil meal make hard butter with a high melting point.

The percentage of lactose in milk cannot be changed by any ordinary method.[12]

307. Effect of feed on minerals in milk.—The percentages of the principal minerals in milk are not changed to any appreciable extent by the amount of these minerals in the feed. In a recent Ohio study the content of calcium, phosphorus, and certain other minerals in the milk produced by cows on improved legume pasture did not differ from that in the milk of cows on permanent bluegrass pasture.[13] Though a ration seriously deficient in phosphorus or calcium will reduce milk production and may cause serious injury to the animal, the milk that is produced will have about the normal content of these minerals.[14]

Milk is very low in iron, as has been stated before. It is apparently impossible to increase the amount by increasing the supply in the feed.[15] (174)

The amount of iodine and the amount of cobalt in cow's milk can be increased decidedly by adding to the ration a supplement supplying the mineral.[16] However, the cow is very inefficient in transferring iodine into her milk.

It has occasionally been advocated that iodine should be added to the rations of dairy cows so that their milk might be used as a goiter preventive for humans in iodine-deficient districts. Most medical authorities agree that the production of such "iodized" milk is inadvisable and unnecessary. The use by humans of iodized salt as insurance against goiter is much cheaper, and the dosage of iodine in this form can be much more easily standardized.

In spite of certain advertising claims to the contrary, the addition of iodine supplements to the rations of dairy cows in careful experiments has not been beneficial in regions where there is no deficiency of iodine in the soil or water. (171) Adding too much iodine to a ration is definitely injurious.

It is of scientific interest, but not generally of any practical importance in stock feeding that the very small amounts in milk of certain other minerals—manganese, zinc, copper, molybdenum, and boron—can be changed somewhat by the supply in the feed.[17]

308. Effect of feed on the vitamin content of milk.—The effect of the ration upon the vitamin content of milk has been considered in the discussions of the various vitamins in Chapter VII. It is emphasized there that the vitamin A value of milk depends on the carotene or vitamin A content of the feed. While milk will be rich in vitamin A if produced by an animal fed a ration having plenty of vitamin A value, the amount of the vitamin will be low if the ration is low in this nutritive essential.

The vitamin A value of milk is of great importance, not only from the standpoint of the value of milk for humans, but also in raising livestock. Information is therefore given in Chapter XXV concerning the vitamin A value of milk produced by cows under various conditions. (1044)

It has been explained in Chapter VII that the vitamin D content of milk is not high from cows fed any ordinary rations. Any considerable increase can be made only by feeding cows large doses of vitamin D in such a form as irradiated yeast.

The content of B-complex vitamins in the milk of non-ruminants is affected considerably by the amounts of these vitamins in their rations. These vitamins are synthesized in the bacterial fermentations occurring in the rumen of ruminants. Therefore ruminants do not require them in their feed, and the content in their milk does not depend chiefly on the amounts in their rations.

The thiamine content of milk is rather low, and the content in cow's milk cannot apparently be increased by feed-

ing yeast or other feeds rich in the vitamin.[18] The amount of riboflavin is somewhat higher when the ration includes a liberal supply of feeds rich in the vitamin, such as green pasturage or other green forage.[19]

Milk contains but little vitamin C, and it is apparently impossible to increase the vitamin C content of cow's milk by the use of feeds rich in the vitamin.[20]

II. The Production of Work

309. The source of muscular energy.—Carbohydrates are the primary and the most efficient source of energy for muscular work. However, fat and protein can also be used indirectly, probably through previous formation of carbohydrates from these nutrients. Under normal conditions, the carbohydrates and the fat of food are first used, and little more or no more protein is broken down than during rest. Should the carbohydrates and fats of the food not furnish enough energy, the body fat is next used. Finally, as a last resort, the muscles or other protein tissues can be called upon, if the energy can be secured from no other source.

Since the greater part of the food of farm animals consists of carbohydrates, most of their muscular energy undoubtedly comes from this source. Also, carbohydrates are apparently the most efficient source of energy for the production of work.

310. Production of muscular work.—We know that in doing work the muscles of the body contract; that is, become shorter and thicker. However, there is still some question as to the manner in which the energy of the food nutrients is converted into muscular movements. Yet some of the processes that take place are definitely known.

In muscular work the glycogen, or animal starch, which has been stored in the muscles during rest, is used up. Increased amounts of oxygen are taken up from the blood, and the amount of carbon dioxide produced in the body is increased in proportion to the amount of work done. Part of the energy in the nutrients used up in the muscular contractions is changed into the mechanical work produced, while part is set free as heat. This latter part is waste energy.

During rest, glycogen is stored in the muscles, forming from 0.5 to 0.9 per cent of the weight of well-nourished muscle when resting. A smaller amount of glucose is also stored in the muscles. During muscular activity, the stored glycogen is used up in proportion to the severity and duration of the work, and after prolonged hard work the supply may be entirely exhausted. Though the amount of glycogen in the muscular tissues at any one time is small, it is replenished from the supply of glucose that is continuously brought to them in the blood.

Physiologists have conducted painstaking experiments in an endeavor to determine the chemical processes that occur in muscular contraction. However, opinions still differ as to the exact reactions which occur. The theory most commonly accepted is that muscular contraction is not caused by energy furnished directly by the oxidation of glycogen or other nutrients.[21] Instead, the energy needed for the contraction apparently comes from the sudden break down of an organic phosphorus compound in the muscle. In this part of the process no oxygen is used up. Another organic phosphorus compound also seems to be involved in the process.

During the relaxation of the muscle, these organic phosphorus compounds are formed again. The necessary energy for their formation is furnished by a conversion of glycogen into an organic acid (lactic acid or pyruvic acid) and oxidation of the organic acid to carbon dioxide and water.

The first part of the process in muscular contraction is therefore somewhat similar to the release of energy by a storage battery. It is not like the production of mechanical energy by a steam engine, where the fuel is burned (oxidized) before the work is performed. The oxidation of nutrients in work occurs *after* the muscular contraction, in the recovery phase of the process.

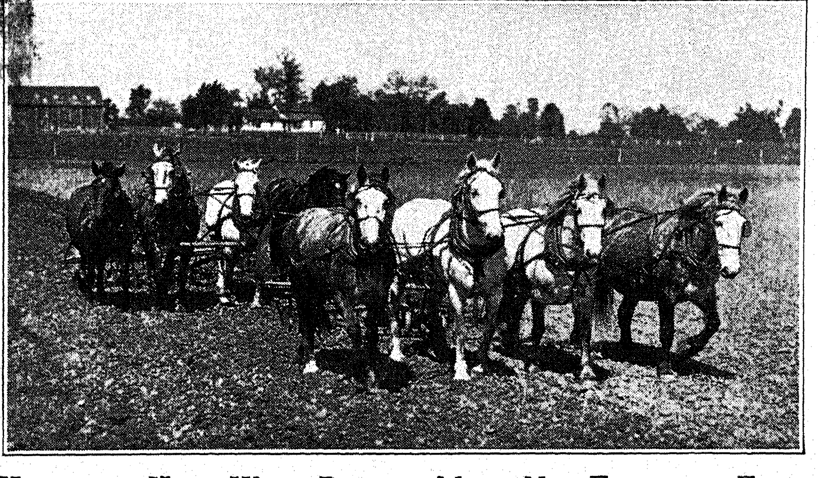
It is for this reason that an animal can perform for a few minutes several times the normal amount of work. For example, a man can temporarily do mechanical work at the rate of a full horse power. This requires several times as much energy as could be liberated by the direct oxidation of nutrients with all the air a man can possibly breathe in per minute.

311. Nutrient requirements for work animals.—The chief need in rations for work animals is a sufficient supply of feeds rich in total digestible nutrients or net energy. A mature animal needs during work but little more protein, minerals, and vitamins than are required for satisfactory maintenance at rest. The requirements for work therefore differ greatly from those for growth, for milk production, or for wool production.

A young work animal that is still growing needs more feed than a mature animal doing the same work. Also, the requirements of a brood mare are increased during pregnancy and especially when suckling her foal. It is important that both these classes of work animals have plentiful supplies of protein, minerals, and vitamins.

The value of any particular feed for work production depends on the amount of net energy it yields. This is because the energy used up in the heat increment, or so-called work of digestion, is all converted into heat, and is wasted so far as the production of work or the formation of body tissues is concerned. (68)

The amounts of digestible nutrients or net energy that are required for any particular work animal will depend on the amount of labor performed. Accordingly, the proportion of concentrates in the ration must be increased as the work becomes harder. For severe work, horses and mules must be fed a liberal amount of such concentrates as the farm grains. On the other hand, animals doing light work can be fed mostly on roughage.



HORSES AT HARD WORK REQUIRE MUCH NET ENERGY IN FEED

On account of the large amount of energy they expend in the work they perform, horses at hard work must receive a liberal amount of concentrates high in net energy.

Many investigations have been conducted to find whether there is any increase in the amount of protein broken down in the body during work, provided there are abundant supplies of carbohydrates and fat. Opinions on this question still differ, but it is agreed, at least, that even during hard work there is no marked increase in the amount of protein used in the body, if the amounts of other nutrients are ample.

For this reason, a mature animal

needs during work but little more protein than is required for satisfactory maintenance at rest. However, as has been shown in Chapter IV, the digestibility of a ration is usually decreased when the proportion of protein is too low. Also, it is believed that a supply of protein somewhat above the minimum requirements tends to give work animals better life and spirit. These factors have been taken into consideration in the recommendations made in the Morrison feeding standards. (Appendix Table III.)

The mature animal when at work does not need a much greater amount of minerals or vitamins than when merely being maintained at rest. However, since a long life of usefulness is important, it is wise to be sure that there is a plentiful supply of these nutrients in the ration.

Detailed discussions of the nutrient requirements of work horses and mules are given in Chapter XXXII. Typical rations which are adapted to various sections of the country are recommended in Appendix Table VII for idle animals and for those performing light, medium, and hard work.

312. Efficiency of the animal as a machine.—It is shown in Chapter XXXII that when horses work at the usual rates they convert into the actual work produced, about 20 to 25 per cent of the energy they expend during the time they are working. The rest of the energy is wasted in the form of heat.

These figures do not take into account the energy lost in the undigested part of the feed and the energy used in maintaining the body when the horse is not working. Allowing for these, a horse doing a full day's work will turn about 9 per cent of the total energy in the feed it eats into actual useful work, such as hauling a load. This efficiency is not far below that of the best gasoline tractors.

The efficiency of the animal is especially striking when it is remembered that the tractor is supplied with purified fuel (kerosene or gasoline) while the horse must secure its energy from crude materials, including hay of which only about half is actually digestible. Furthermore, he must digest his feed and separate the useful from the waste material. Also, he must make all body repairs. Last, but not least, he must maintain his body during the part of the 24 hours that he is not working, while all expenditures of energy cease when the tractor stops work.

313. Factors influencing energy required for work.—The amount of energy required to produce a given amount of useful work depends upon many factors. Practice in doing a certain kind of work lessens the amount of energy expended.

On the other hand, fatigue greatly increases the energy required to do a task. This is largely due to the fact that with increasing fatigue the muscles normally used, and which are thus most efficient in performing the given work, are put out of use by the exhaustion of nutrient reserves or the accumulation of waste products. Then other less efficient muscles are called upon to a constantly increasing degree, and these cannot perform the work so economically.

Increasing the speed at which the work is done also lessens the efficiency with which it is performed. This is because the work of the heart is increased, the body temperature rises, and much heat is lost by the evaporation of water through the skin and lungs. This decreases the amount of work that a given quantity of feed will produce. Furthermore, when a horse trots or gallops, the rise and fall of the body is much greater than in walking, and therefore it has available for onward movement less of the total energy that is expended.

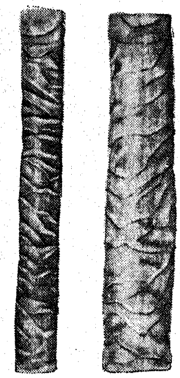
The portion of the expended energy which is converted into useful work varies with the build of the animal, the development of its muscles, and the structure of its limbs. For example, a lame horse may use nearly twice as much energy in traveling a certain distance as one with sound legs. An animal which is able to perform one kind of work most economically may have to expend undue energy at other kinds of work. Thus, horses bred for generations to the saddle can carry the rider with a smaller expenditure of energy than those whose

breeding and form specially fit them for draft purposes.

Additional discussions of the factors influencing the production of work, as applied to horses, are given in Chapter XXXII.

III. Wool Production

314. Composition of wool.—Wool fibers are practically pure protein and are of the same chemical composition as hair, but they differ from hair in being covered with minute overlapping scales.



Wool Fibers

Appearance of fibers, greatly magnified, after dirt and yolk have been removed. Left, fiber of Merino wool; right, fiber of Down wool. Note the overlapping scales covering the fibers.

These give wool its characteristic valuable properties as a textile. In addition to the wool fibers, raw wool contains a large proportion of adhering material which must be removed by scouring before the wool is manufactured into cloth.

Most raw wool shrinks 50 to 65 per cent on being scoured. In other words, only 35 to 50 lbs. of dry, clean wool fiber are secured from each 100 lbs. of raw wool. The shrinkage is made up of wool grease, suint, dirt, adhering chaff or other plant material, and moisture. The value of a fleece of wool depends first of all on the weight of clean, scoured wool it will yield, and then on the nature and quality of the wool fiber.

The shrinkage is greater for fine wool than for coarser wool, as fine wool contains much more grease. It is usually higher for wool from range sheep than from those kept under farm conditions, as the range wool usually carries more dirt and extraneous material.

The wool grease is important in protecting the fiber from injury by the weather. It is largely made up of combinations of cholesterol with fatty acids, and is therefore not a true fat. The suint is chiefly composed of potassium salts of various fatty acids. As it is soluble in water, there is less in sheep exposed to the weather. The term "yolk" is applied to the wool grease and suint combined, and sometimes to the wool grease alone.

315. Requirements for wool production.—Because of the wool they produce, sheep need a somewhat larger supply of protein and also of total digestible nutrients than do cattle or swine at the same stage of maturity. This is taken into consideration in the feeding standards for the various classes of sheep. (Appendix Table III.) For growing lambs, pregnant ewes, and ewes suckling lambs, there is a double need for protein. The nutrient needs of sheep and lambs are discussed in detail in Chapters XXX and XXXI.

The mohair produced by Angora goats has the same general chemical composition as wool fiber, though differing in structure. Therefore the nutrient requirements of these goats are similar to the requirements of sheep. The requirements of milk goats, on the other hand, resemble those of dairy cows.

Sickness, undue exposure, or a decided lack of feed will decrease the yield of wool, will produce smaller and weaker fibers, and will sometimes even cause weak spots in the fibers.[22] Wool that has a weak spot is said to have a "break" or to be "tender." Unless the undernutrition is severe, the amount of yolk (wool grease plus suint) will be decreased more than the yield of scoured wool.

In a California trial sheep produced more than three times as much scoured wool when fed a liberal fattening ration for 6 months as when poor-quality alfalfa hay was fed in amounts not quite sufficient to maintain their weights.[23] The

wool fibers were only half as strong on the sub-maintenance ration, and they were seriously lacking in crimp. In a Nebraska trial lambs fed a liberal ration for about a year produced more than twice as much scoured wool as others given slightly less than a maintenance ration.[24] The wool fibers produced on the scanty ration were shorter and much smaller in diameter.

Exposure and insufficient feed, such as sheep are often subjected to under range conditions during the winter, will considerably reduce the yield of scoured wool, in comparison with the yield under better conditions of feeding and shelter.[25] Louisiana experiments show that serious underfeeding of sheep may even cause shedding of the wool, which sometimes occurs in sheep, even when not infected with scab.[26]

If lambs are fed so that they make rapid gains, they will have larger bodies at a given age and be more mature than if fed somewhat less liberally. They will consequently shear heavier fleeces.

In most of the tests that have been reported, ewes have had heavier fleeces at 2 to 3 years of age than as yearlings.[27] Rambouillets reach maximum fleece weights somewhat later than the mutton breeds. After 3 to 4 years the fleece weight gradually declines with increasing age. In Texas studies the diameter of the wool fibers of Rambouillet sheep remained relatively constant throughout the useful life of the sheep. The length of the fibers was greatest the first year and declined after the fourth year.[28] Ewes producing lambs yielded slightly less wool than did ewes that had no lambs, and their wool was a trifle shorter.

QUESTIONS

1. Describe the structure of the udder, and tell what is known about the manner in which milk is secreted.
2. What is probably the source of the following constituents of milk: (a) Protein; (b) fat; (c) lactose?
3. When is milk secreted?
4. Describe the development of the mammary gland after the animal reaches sexual maturity; after pregnancy occurs.
5. Discuss the use of hormones to cause milk production.
6. Compare the nutrient requirements of a lactating animal with the requirements for maintaining a mature animal. Consider protein, minerals, vitamins, and total digestible nutrients or net energy in your discussion.
7. Discuss the protein requirements for milk production. About how much digestible protein does a dairy cow require in her feed, in addition to the maintenance requirement, for each pound of protein she produces in her milk?
8. Discuss the total digestible nutrient or net energy requirements for milk production.
9. From what food sources can the fat in milk be formed? Of what importance is the percentage of fat in a concentrate mixture for dairy cows?
10. To what extent can the composition of milk be changed by the feed an animal receives? Consider: (a) Protein; (b) percentage and character of fat; (c) lactose; (d) minerals; (e) vitamin A value.
11. From what food nutrients can muscular energy be produced?
12. Describe some of the chief processes that occur in the production of muscular movements.
13. Compare the requirements for a work animal with those for maintaining the same animal when idle, considering: (a) Total digestible nutrients or net energy; (b) protein; (c) minerals and vitamins.
14. Discuss the efficiency of the animal as a machine for the production of work.
15. What are the effects of fatigue, speed, lameness, and build of the animal on the economy with which work is produced?
16. Of what is wool composed?
17. Discuss the food requirements for wool production, and state what effects unfavorable feed or conditions may have upon wool.

REFERENCES

1. For further information on the structure of the udder and the physiology of milk secretion see: Espe, Secretion of Milk, 3rd Ed., 1946; Turner, The Comparative Anatomy of the Mammary Glands, 1939; Turner, Mo. Buls. 339, 344, 346; Elliott and Turner, Mo. Res. Bul. 537; Petersen, Minn., Jour. Dairy Sci., 25, 1942, pp. 71–96; Petersen, Minn., Physiol. Reviews, 21, 1944, pp. 340–371.
2. Swett, Miller, Graves, Black, and Creech,

U.S.D.A., Jour. Agr. Res., 55, 1937, pp. 239–287.
3. Petersen, Minn., Jour. Dairy Sci., 25, 1942, pp. 71–96.
4. Reviewed in Espe and Smith, Secretion of Milk, 4th Ed. See also: Kleiber et al., Cal., Jour. Biol. Chem., 197, 1952, pp. 365–370, 371–379; Mix, Peterson, and Struss, Minn., Jour. Dairy Sci., 35, 1952, p. 504; Maynard, McCay, Ellis, Hodson, and Davis, N.Y. (Cornell) Memoir 211; Reineke, Peterson, Houchin, and Turner, Mo. Res. Bul. 296; Folley and French, England, Biochem. Jour., 46, 1950, pp. 465–473; Campbell and Work, England, Biochem. Jour., 52, 1952, p. 217.
5. Swett, U.S. Dept. Agr., Jour. Dairy Sci., 10, 1927, pp. 1–14; Swett, Miller, and Graves, Jour. Agr. Res., 45, 1932, pp. 385–419, 577–607; Gaines, Ill., Amer. Jour. Physiol., 38, 1915, pp. 285–312; Gaines and Sanmann, Ill., Amer. Jour. Physiol., 80, 1927, pp. 691–701; Gowen and Tobey, Maine, Jour. Gen. Physiol., 12, 1928, pp. 123–128; Petersen, Palmer, and Eckles, Minn., Amer. Jour. Physiol., 90, 1929, pp. 573–581; Ragsdale, Turner, Brody, Elting, and Gifford, Mo. Buls. 244, 256.
6. Meites and Turner, Mo. Res. Bul. 415.
7. Johannsson and Knudson, Wis., Jour. Dairy Sci., 16, 1933, pp. 523–528.
8. Marshal, Becker, Dix Arnold, and Sanders, Fla. Bul. 440; Dalton, Ga., Jour. Dairy Sci., 38, 1955, p. 610; Meites, Reineke, and Cairy, Mich., Jour. Dairy Sci., 35, 1952, p. 504; Hill, Minn., Jour. Dairy Sci., 35, 1952, p. 504; Dziuk, Koshi, and Petersen, Minn., Jour. Anim. Sci., 14, 1955, p. 1080; Yamamoto and Turner, Mo., Jour. Dairy Sci., 38, 1955, p. 609; Wrenn and Sykes, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 1313–1318; Day and Hammond, England, Jour. Agr. Sci., 35, 1945, pp. 150–157.
9. Washburn, Brody, and Ragsdale, Mo. Res. Bul. 295; Brody Bioenergetics and Growth, 1945, pp. 820–827; Ritzman and Benedict, N.H. Bul. 296.
10. Jordan, Jenter, and Fuller, N.Y. (Geneva) Buls. 132, 197.
11. Perkins, Krauss, and Hayden, Ohio Bul. 515.
12. Whitnah, Riddell, and Hodgson, Kan., Jour. Dairy Sci., 16, 1933, pp. 347–353; Petersen and Brown, Minn., Abstr. of Papers, 29th Ann. Meeting, Amer. Dairy Sci. Assoc., 1934.
13. Washburn, Hibbs, and Sayre, Ohio Res. Cir. 13.
14. Forbes et al., Penn. Bul. 319; Archibald, Rice, and Parsons, Mass., Bul. 347; Associates of Rogers, Fundamentals of Dairy Science, 2nd Ed., pp. 584–587.
15. Waddell, Steenbock, and Hart, Wis., Jour. Nutr., 4, 1931, pp. 53–65; Archibald and Parsons, Mass. Bul. 378; Krauss and Washburn, Ohio Bul. 532.
16. Maynard, N.Y., Cornell Veterinarian, 19, 1929, pp. 125–138; Associates of Rogers, Fundamentals of Dairy Science, 2nd Ed., pp. 584–587; Archibald, Mass., Jour. Dairy Sci., 30, 1947, pp. 293–297.
17. Archibald and Lindquist, Mass., Jour. Dairy Sci., 26, 1943, pp. 325–330; Archibald, Jour. Dairy Sci., 27, 1944, pp. 257–261; 32, 1949, pp. 877–880; 34, 1951, pp. 1026–1029; 38, 1955, pp. 159–162; Hove, Elvehjem, and Hart, Wis. Bul. 446.
18. Krauss and Hunt, Ohio Buls. 470, 516; Gunderson and Steenbock, Wis., Jour. Nutr., 5, 1932, pp. 199–212.
19. Maynard and Johnson, N.Y. (Cornell) Rpt. 1939; Johnson, Maynard, and Loosli, N.Y., Jour. Dairy Sci., 24, 1941, pp. 57–64; Hunt, Krauss, and Monroe, Ohio Bul. 561.
20. Riddell and Whitnah, Kan., Jour. Dairy Sci., 21, 1938, pp. 121–122; Riddell, Whitnah, Hughes, and Leinhardt, Kan., Jour. Nutr., 11, 1936, pp. 47–54; Sharp, N.Y., Science, 84, 1936, pp. 461–462.
21. Dukes, The Physiology of Domestic Animals, 7th Ed., 1955, pp. 708–710.
22. Miller, Cal. Rpt. 1930; Snell, La. Rpt. 1929–31; Joseph, Mont., Jour. Agr. Res., 33, 1926, pp. 1073–89.
23. Wilson, Cal., Amer. Soc. Anim. Prod., Proc. 1930; see also: Bowstead and Larose, Canadian Jour. Res., 16, 1938, Sec. D, pp. 361–374; Fraser and Nichols, Empire Jour. Expt. Agr., 2, 1934, pp. 9–19; 3, 1935, pp. 75–79; Sullivan, Hess, and Howe, Jour. Agr. Res., 61, 1940, pp. 877–886.
24. Weber, Nebr., Amer. Soc. Anim. Prod., Proc. 1931.
25. Esplin, Utah Bul. 240; see also: Bell, Spencer, and Hardy, Ohio Bul. 571.
26. Snell, La. Bul. 269.
27. Spencer, U.S.D.A., Amer. Soc. Anim. Prod., Proc. 1925–26, pp. 97–101; Horlacher, Ky. Rpt. 1923; Snell, La. Rpt. 1929–31; Vaughan, Joseph, and Vinke, Mont. Rpt. 1929; Jones, Dameron, Davis, Warwick, and Patterson, Tex. Bul. 657; Wyo. Rpt. 54.
28. Jones, Dameron, Davis, Warwick, and Patterson, Tex. Bul. 657; see also: Briggs, Okla. Rpt. 1936–38.

CHAPTER XI

BALANCED RATIONS—FEEDING STANDARDS

I. Balanced Rations

316. Purpose of feeding standards.—To guide farmers in selecting properly balanced rations for their livestock, scientists have prepared *feeding standards.* These are tables stating the amounts of nutrients which, it is believed, should be provided in rations for farm animals of the various ages and classes in order to secure the best results.

Before reviewing the history of feeding standards and comparing the recommendations made by various scientists, let us compute a ration, balanced according to the recommendations of a feeding standard, to show how these aids in stock feeding are used. We will compute the ration according to the total digestible nutrient method, as this is the method most commonly used in the United States.

Previous to computing a ration for any class of stock, one should be sure that he has in mind the general requirements of satisfactory rations for that class of stock. These are discussed in the respective chapters of Part III.

317. A balanced ration for a dairy heifer.—Let us assume that a dairy farmer wishes to compute a balanced winter ration for a dairy heifer weighing 400 lbs., which is no longer being fed milk. He has available plenty of good alfalfa hay, ground corn grain (No. 2 grade), and ground oats. A study of the practical recommendations in Chapter XXVII for feeding dairy heifers shows that these feeds, in proper combination, are excellent for this purpose.

The next step is to find the amounts of nutrients recommended for heifers of this age in an up-to-date feeding standard. By turning to Appendix Table III, which presents the complete Morrison feeding standards, we find that the recommendations for a 400-lb. dairy heifer per head daily, according to these standards, are as follows: Dry matter, 9.1 to 11.4 lbs.; digestible protein, 0.76 to 0.87 lb.; and total digestible nutrients, 6.0 to 7.0 lbs.

The standards also show that the ration for such a heifer should contain 13 grams (0.029 lb.) of calcium, 9 grams (0.020 lb.) of phosphorus, and 24 milligrams of carotene. We will first compute a balanced ration that meets the recommendations for digestible protein and total digestible nutrients, and then see if it supplies sufficient calcium, phosphorus and carotene.

The Morrison feeding standards also state the amounts of net energy, expressed in therms, that are recommended for the various classes of animals. These net energy recommendations are used, instead of the amounts of total digestible nutrients, if one wishes to compute a ration according to the net energy system. (68) They are not used at all in computing a ration according to total digestible nutrients.

The amounts of dry matter recommended in the standard mean that a heifer of this size has a digestive tract that is sufficiently large for her to consume 9.1 to 11.4 lbs. of dry matter a day in her feed. This amount of feed should furnish 0.76 to 0.87 lb. digestible protein and 6.0 to 7.0 lbs. total digestible nutrients.

For two different reasons, a range is indicated in the amounts of digestible protein, of total digestible nutrients, and of dry matter recommended in the Morrison standards. First, economic conditions should determine whether it is better to use the lower or the higher figures for digestible protein or for total digestible nutrients. When protein-rich feeds are not unduly expensive, the author be-

lieves it is best to supply enough digestible protein to meet the higher recommendations. On the other hand, when protein supplements are unusually high in price, it may be more economical to furnish only enough digestible protein to meet the lower recommendations.

Similarly, the author believes that the results will generally be best when livestock are fed the higher amounts of total digestible nutrients stated in the standards. However, when grain and other concentrates are unusually expensive compared with roughages, it will be more economical to follow the lower recommendations and feed less concentrates.

50.7 per cent of total digestible nutrients. According to the standards, the heifer should receive 6.0 to 7.0 lbs. of total digestible nutrients a day. As we desire the heifer to make excellent growth, we will feed her a ration that will supply about 7.0 lbs. of total digestible nutrients.

Since each pound of hay furnishes 0.507 lb. of total digestible nutrients, the amount of hay needed to provide approximately this amount of total digestible nutrients can be found by dividing 7.0 lbs. by 0.507 lb. This gives a result of 13.8 lbs. This amount of hay will furnish the amounts of dry matter and digestible nutrients shown in the table:

First trial ration for 400-lb. dairy heifer

	Dry matter Lbs.	Digestible protein Lbs.	Total digestible nutrients Lbs.
Requirements	9.1–11.4	0.76–0.87	6.0–7.0
Alfalfa hay, 13.8 lbs.	12.5	1.50	7.00

The second reason for having a range in the amounts of nutrients recommended in the standards is that feeding standards can be only approximate guides. It has been pointed out in previous chapters that individual lots of the same kind of feed may differ considerably in chemical composition and in feeding value. Also, individual animals differ in ability to digest and utilize feeds.

In general, a ration made up of suitable feeds will be satisfactory, if the amounts of dry matter and of digestible nutrients fall within the limits set in the standard for that particular animal.

318. Computing the ration.—Before proceeding to compute a balanced ration, one should first write down in tabular form the requirements for the particular animal, as in the following table.

Let us next see how nearly a ration of only alfalfa hay would come to meeting the requirements for this heifer. Appendix Table I shows that alfalfa hay of average quality (alfalfa hay, all analyses) supplies 90.5 per cent of dry matter, 10.9 per cent of digestible protein, and

This ration supplies even more digestible protein than necessary and furnishes 7.00 lbs. of total digestible nutrients, but it is too high in dry matter. This means that the ration is too bulky and that it is too low in digestible nutrients per pound of dry matter. In other words, the heifer will not be able to eat enough hay to meet fully her need for total digestible nutrients. To make the ration satisfactory, it is therefore necessary to replace part of the hay by grain or other concentrates.

In the discussion of rations for dairy heifers in Chapter XXVII, it is stated that when heifers of this age are fed good roughage, an allowance of 2 to 4 lbs. of concentrates per head daily should be enough. **(1149)** It is also stated there that, when heifers are fed plenty of legume hay as the only roughage, grain alone is satisfactory for the concentrates.

Let us therefore see if the requirements will be met fully, if we use 3 lbs. of a mixture of one-half ground corn (Grade No. 2) and one-half ground oats, and reduce the amount of hay, so that the amount of total digestible nutrients will be about the same as before.

This will make possible the reducing of the hay allowance to 9.4 lbs. a day. The ration will then provide the following:

Balanced ration for 400-lb. dairy heifer

	Dry matter Lbs.	Digestible protein Lbs.	Total digestible nutrients Lbs.
Requirements	9.1–11.4	0.76–0.87	6.0–7.0
Ration			
Alfalfa hay, 9.4 lbs.	8.51	1.02	4.77
Corn, No. 2, 1.5 lbs.	1.28	0.10	1.20
Oats, 1.5 lbs.	1.35	0.14	1.05
Total	11.14	1.26	7.02

This ration supplies 7.0 lbs. total digestible nutrients, and the amount of dry matter comes within the range indicated in the standard. The amount of digestible protein is considerably higher than necessary, but this surplus of protein will not be at all detrimental. (108)

We should next see whether this ration provides sufficient calcium, phosphorus, and carotene. The percentages of calcium and phosphorus in these feeds are given in Appendix Table I and the amounts of carotene, expressed in terms of milligrams per pound, in Appendix Table V. From these data, we will find on computation that this ration supplies 0.140 lb. of calcium, while the requirement is only 0.029 lb. There is therefore an abundance of calcium. This is due to the high calcium content of alfalfa hay.

The ration has 0.032 lb. phosphorus, which is well above the requirement of 0.020 lb.

If the alfalfa hay is of reasonably good quality, it should supply 9 milligrams of carotene per pound. The 9.4 lbs. of hay would thus furnish 84.6 milligrams of carotene, which is more than three times the minimum stated in the standard. In addition, if the corn is yellow corn, it will supply some carotene. Oats have practically no carotene.

There is therefore no need of any additional supply of calcium, phosphorus, or carotene.

319. A balanced ration with roughage low in protein.—If good legume hay had not been used as the only roughage or at least as the chief roughage for this heifer, it would have been necessary to feed a protein supplement to balance the ration. Let us suppose, for example, that only timothy hay and corn silage are available for roughages. Timothy hay of the usual quality is not very good as the only roughage for heifers, but satisfactory results can be secured, when it is combined with corn silage, and when sufficient protein supplement is fed.

Let us then see how nearly the requirements for this heifer will be met by a ration of 6.0 lbs. of timothy hay (average of all analyses in Appendix Table I), 10.0 lbs. of corn silage (corn silage, dent, well-matured, recent analyses), and the same amounts of corn and oats as in the preceding ration. We will then have the following:

Ration too low in protein for 400-lb. heifer

	Dry matter Lbs.	Digestible protein Lbs.	Total digestible nutrients Lbs.
Requirements	9.1–11.4	0.76–0.87	6.0–7.0
Ration			
Timothy hay, 6.0 lbs.	5.34	0.18	2.95
Corn silage, 10.0 lbs.	2.76	0.12	1.83
Corn, No. 2, 1.5 lbs.	1.28	0.10	1.20
Oats, 1.5 lbs.	1.35	0.14	1.05
Total	10.73	0.54	7.03

This ration falls considerably below the requirements in digestible protein. To balance it, let us replace some of the corn-and-oats mixture with linseed meal (linseed meal, expeller or hydraulic process, average of all analyses, in Appendix Table I).

The next step is to find how much of the corn-oats mixture must be replaced by linseed meal. The ration has only 0.54 lb. digestible protein. To bring it up to the higher allowance recommended in the standard, the amount of digestible protein must be increased by 0.33 lb. (0.87 lb. – 0.54 lb. = 0.33 lb.)

The 3 lbs. of corn-and-oats mixture has a total of 0.24 lb. digestible protein (0.10 lb. + 0.14 lb. = 0.24 lb.). Therefore, each pound of this mixture supplies 0.08 lb. digestible protein.

Appendix Table I shows that average linseed meal has 30.6 per cent digestible protein. Each pound thus furnishes 0.306 lb. digestible protein.

By replacing 1.0 lb. of the corn-oats mixture with 1.0 lb. of linseed meal, the amount of digestible protein will be increased 0.226 lb. (0.306 lb. – 0.080 lb. = 0.226 lb.). To find the amount of linseed meal that we must substitute for the corn-oats mixture, we divide 0.33 lb. (the increase needed) by 0.226 lb. (the increase made by substituting 1.0 lb. of linseed meal for 1 lb. of the corn-oats mixture). This gives us 1.5 lbs. as the answer. Thus to balance the ration in protein, it will be necessary to replace 1.5 lbs. of the corn-oats mixture with 1.5 lbs. of linseed meal.

If some such method is not used to find how much protein supplement is needed, it is often necessary to try out several combinations of feeds, before one finds the proper mixture to balance the ration. Time can also often be saved by using this method of computation, when the ration is either too low or too high in total digestible nutrients, and one wishes to make a certain definite change in the amount of total digestible nutrients by changing the proportions of roughage and concentrates.

The following table shows that this ration meets the requirements:

Second balanced ration for 400-lb. heifer

	Dry matter Lbs.	Digestible protein Lbs.	Total digestible nutrients Lbs.
Requirements	9.1–11.4	0.76–0.87	6.0–7.0
Ration			
Timothy hay, 6.0 lbs.	5.34	0.18	2.95
Corn silage, 10.0 lbs.	2.76	0.12	1.83
Corn, No. 2, 0.75 lb.	0.64	0.05	0.60
Oats, 0.75 lb.	0.68	0.07	0.53
Linseed meal, 1.5 lbs.	1.37	0.46	1.13
Total	10.79	0.88	7.04

This ration should be satisfactory, but it is not so good as a ration containing some legume forage.

It will be found on computation that this ration supplies an abundance of phosphorus, because of the high phosphorus content of linseed meal. It is stated in Chapter XXVII that there will generally be no lack of calcium for heifers fed plenty of roughage, even when it is non-legume, unless the soil is unusually low in calcium. (**1116**) By computation, it will be found that, according to average analyses, this ration supplies 0.037 lb. calcium, which is slightly above the requirement in the standard. However, when heifers are fed no legume forage whatsoever, it may be wise to supply a calcium supplement, to guard against a possible deficiency, if the hay and silage are lower than average in calcium.

Because of the good carotene content of corn silage, the ration will provide ample carotene.

320. "Square" method of balancing ration.—Another method of determining how much protein supplement is needed to balance a ration is the "square" method, which is used at milk plants to

find what proportions of milk and heavy cream, the fat percentages of which are known, are needed to make cream or milk containing a certain desired percentage of fat.

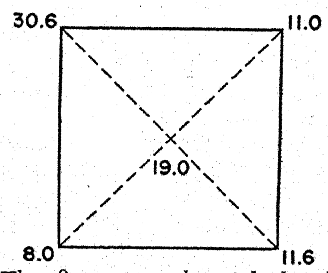
Let us employ this method to find what proportions of linseed meal and of the corn-oats mixture are needed to balance the same allowances of roughages used in the previous ration. The preceding table shows that the combination of 6.0 lbs. timothy hay and 10.0 lbs. corn silage furnishes a total of 0.30 lb. digestible protein.

To provide 0.87 lb. digestible protein in the entire ration, the concentrates must therefore provide 0.57 lb. digestible protein. If 3 lbs. of concentrate mixture are fed a day, each pound of the mixture must have 0.19 lb. digestible protein, or the percentage of digestible protein must be 19.0 per cent.

The question is, what proportions of linseed meal, having 30.6 per cent digestible protein, and of the corn-oats mixture, which we have previously found to have 8.0 per cent digestible protein, will give a mixture with 19.0 per cent digestible protein?

To use the "square" method, set down the percentages of digestible protein in the two components of the mixture at the left hand corners of a square. Connect the diagonal corners of the square with lines, and set down the desired percentage of protein in the center.

Then follow along the diagonal lines and set down in the right hand corners the differences between the figures at the left-hand corners and the figure in the center. The square will then appear as follows:



The figures at the right-hand corners show the proportions of linseed meal and of the corn-oats mixture it will take to give a digestible-protein content of 19.0 per cent. The number showing the parts of linseed meal in the mixture is directly opposite the percentage of protein in linseed meal, and the number showing the parts of the corn-oats mixture is opposite the percentage of protein in this mixture.

It is found by this simple method that a mixture composed of 11.0 parts or pounds of linseed meal and 11.6 parts or pounds of the corn-oats mixture will have the desired digestible protein content of 19.0 per cent. There will be 11.0 parts plus 11.6 parts, or 22.6 parts in the total combination.

The number of pounds of linseed meal in 100 lbs. of the mixture is found by dividing 11.0 by 22.6 and multiplying the quotient by 100. This gives us 48.7 lbs. of linseed meal in 100 lbs. of mixture. The rest, or 51.3 lbs., is the combination of one-half corn and one-half oats.

To simplify making up the mixture, it will be accurate enough if it is made up of 50 lbs. linseed meal, 25 lbs. ground corn, and 25 lbs. ground oats. It will be found that such a mixture, made from feeds of average composition, will supply 19.3 per cent digestible protein. The protein requirements will therefore be met well if 3 lbs. per head daily of this mixture are fed.

321. Finding the formula for a concentrate mixture.—In the practical feeding of livestock, it is not necessary to compute balanced rations for the individual animals in the herd or flock. Instead, a ration is found that will provide the proper amounts of nutrients for the average animal. Then, the amount of concentrates, or of both concentrates and roughage, may be varied for the various animals.

For example, in feeding a herd of dairy cows, the same concentrate mixture, or so-called "grain mixture," is generally used for all the cows, except perhaps for those that are exceptionally high producers. However, the *amount* of the concentrate mixture fed each cow should depend on her actual milk pro-

duction, as is emphasized in Chapter XXV.

The Grain Feeding Tables, given in Appendix Tables VIIIa and VIIIb, state definitely the amounts of grain mixture, or concentrate mixture, needed daily by cows producing different amounts of milk of the various fat percentages, and when supplied with different qualities and amounts of roughages. One of these tables is for barn feeding and the other for cows on different qualities of pasture. The use of these tables and the Example Rations given in Appendix Table VII will save much time in computing balanced rations for dairy cows.

322. Formula for a concentrate mixture.—To illustrate the way the formula for a concentrate mixture is found, let us compute a concentrate mixture, made up of ground corn, ground oats, wheat bran, and soybean oil meal, for feeding the same age of dairy heifers as in the previous example. We will use the same roughages as in the preceding example —6 lbs. of average timothy hay and 10 lbs. of well-matured corn silage.

We have seen in the preceding examples that 3 lbs. of a concentrate mixture are sufficient for such heifers. Also, in the ration with timothy hay and corn silage for roughage, it has been shown that to meet the higher protein recommendations in the standard, the concentrate mixture should have about 19.0 per cent digestible protein. This high protein content is needed, because no legume forage is available.

Let us now find the proportions of corn, oats, wheat bran (all analyses), and soybean oil meal (expeller or hydraulic process, 43 per cent protein guarantee) that will furnish this percentage of digestible protein. We will first try a mixture of 25 lbs. of each of these feeds. From Appendix Table I, we find that this mixture will supply the following amounts of digestible protein:

	Digestible protein Lbs.
Corn, No. 2, 25 lbs.	1.68
Oats, 25 lbs.	2.35
Wheat bran, 25 lbs.	3.33
Soybean oil meal, 25 lbs.	9.23
	16.59

Since 100 lbs. of this mixture contain 16.59 lbs. of digestible protein, the percentage of digestible protein is 16.59 per cent. This is somewhat less than is needed. We must therefore increase the proportion of a protein-rich feed in the mixture and decrease the amount of another feed correspondingly.

We desire to feed as large a proportion of home-grown corn and oats as possible. Since soybean oil meal is much richer than wheat bran in protein, we will increase the soybean oil meal and reduce the wheat bran. By trying out various combinations, we find that a mixture of 25 lbs. ground corn, 25 lbs. ground oats, 14 lbs. bran, and 36 lbs. soybean oil meal will have the desired percentage of digestible protein.

Let us now find the percentages of dry matter and of digestible nutrients in the concentrate mixture. This is done as follows:

Finding the composition of a concentrate mixture

	Dry matter Lbs.	Digestible protein Lbs.	Total digestible nutrients Lbs.
Corn, No. 2, 25 lbs.	21.25	1.68	20.03
Oats, 25 lbs.	22.55	2.35	17.53
Wheat bran, 14 lbs.	12.61	1.86	9.37
Soybean oil meal, 36 lbs.	32.90	13.28	28.30
In 100 lbs. of mixture	89.31	19.17	75.23

Having found the composition of this concentrate mixture, we can use these figures in working out a ration, just like the figures in Appendix Table I for the various single feeds. Let us now check this ration to see whether it fully meets the needs of 400-lb. dairy heifers. We will then have the following:

Balanced ration, using preceding concentrate mixture

	Dry matter Lbs.	Digestible protein Lbs.	Total digestible nutrients Lbs.
Requirements	9.1–11.4	0.76–0.87	6.0–7.0
Ration			
Timothy hay, 6.0 lbs.	5.34	0.18	2.95
Corn silage, 10.0 lbs.	2.76	0.12	1.83
Concentrate mixture, 3.0 lbs.	2.80	0.58	2.26
Total	10.90	0.88	7.04

This ration fully meets the requirements stated in the standard.

323. Finding the percentage of protein needed in a mixed feed.—If one desires to use a commercial mixed feed instead of a home-prepared concentrate mixture, the question arises as to the percentage of protein needed in the mixed feed to make a balanced ration with the roughage available.

In the case of most mixed feeds on the market, while the percentage of total protein is guaranteed, the percentage of digestible protein in the feed is not stated. Therefore, it is necessary to find the approximate percentage of total protein required in the mixed feed to make a balanced ration with the roughage that is to be fed. This can be done as follows:

Let us assume that by such computations as in the previous examples, we have found that with plenty of good-quality mixed clover-and-timothy hay and corn silage for roughage, a herd of dairy cows needs a concentrate mixture having about 14.5 per cent digestible protein to make a balanced ration.

In most good mixed dairy feeds approximately 80 per cent of the total protein is digestible. On this basis, the necessary percentage of total protein in a mixed feed may be found by dividing 14.5 per cent by .80 and multiplying by 100. This gives us a result of 18.1 per cent, which means that a good-quality mixed feed which supplies 14.5 per cent *digestible protein* will contain about 18 per cent *total protein.* A mixed dairy feed that is guaranteed to contain 18 per cent protein should therefore be satisfactory for feeding with such roughage.

324. Guides in selecting efficient balanced rations.—Before attempting to compute economical balanced rations for any class of stock, it is important to read the explanations and general hints in the following paragraphs and in the next chapter. Also, one should study the information given in Part III on how to make up efficient rations for that particular class of stock. It is impossible to compute satisfactory and economical rations if reliance is placed only on the amounts of nutrients recommended in feeding standards.

As a guide to students and stockmen alike, the author has computed example balanced rations for the different classes of stock, which are adapted to various conditions. These rations are given in Appendix Table VII. Often, one will be able to find among these suggestions a ration that will exactly meet his particular conditions. Even when the feeds that are available differ somewhat from those included in the example rations, these rations will serve as convenient guides and will save much time in computation.

Unless a person is experienced in stock feeding, he may not know what proportions or amounts of roughages and concentrates there should be in rations for any class of stock. As has already been shown in this chapter, the amounts of dry matter and of total digestible nutrients recommended in the feeding standard for a particular kind of stock are a guide to the proper proportion of roughages and concentrates in the ration.

When the requirement of digestible nutrients or of net energy is high compared with the total amount of dry mat-

ter advised, the proportion of concentrates in the ration must be large to meet the standard. On the other hand, for merely maintaining horses, cattle, or sheep the allowance of digestible nutrients or net energy is much smaller, in comparison with the amount of total dry matter. This is because these animals can be maintained largely or entirely on roughage.

In Appendix Table III there will be found, immediately previous to the Morrison feeding standards, convenient guides which show the approximate proportions of roughages and concentrates required by the various classes of stock. By referring to these guides, much time can often be saved in computing balanced rations.

AN UNSATISFACTORY AND EXPENSIVE "BALANCED" RATION

This ration of 20 lbs. late-cut timothy hay, 3 lbs. ground corn, 2 lbs. ground oats, 3 lbs. wheat bran, and 3.5 lbs. linseed meal, meets the standard for a 1,200-lb. cow yielding 30 lbs. of 3.5 per cent milk. However, late-cut timothy hay is a poor roughage for dairy cows, because it is unpalatable, poor in protein, and low in total digestible nutrients. A cow will not eat as much of such hay as of good-quality hay. Therefore, 11.5 lbs. of concentrates are needed. Even then, the milk production will be lower than with good roughage. (From Wisconsin Station.)

II. GENERAL REQUIREMENTS FOR SATISFACTORY RATIONS

325. Feeding standards only approximate guides.—It has been shown in Chapter IV that there may be considerable difference in the composition and feeding value of two different lots of the same kind of feed. Also, individual animals may differ somewhat in their ability to digest and utilize feed. These facts must be taken into consideration in the preparation of feeding standards. The recommendations must therefore provide a sufficient margin of safety to cover the usual variations in the composition of feeds and the differences in the individual animals to be fed.

Animals on pasture need a somewhat greater amount of total digestible nutrients per head daily than those confined to a stable most of the time. This is because of the additional energy used up in the muscular work of grazing.

The author believes that, except when protein-rich feeds are unusually expensive, it is best to supply about as much protein as called for by the higher set of recommendations in the standards. On the other hand, if protein supplements are high in price, in comparison with grains or other low-protein feeds, it will probably be more economical to provide no more than the lower amounts of digestible protein in the standards.

When protein supplements are extremely high in price, it may be most economical to feed slightly less protein than called for by the lower set of recommendations, even though the rate of production may be decreased somewhat. At the other extreme, when protein-rich feeds are cheaper than those low in pro-

tein, it is usually economical to furnish even a greater amount of protein than stated in the higher set of protein allowances in the standards. As has been shown in Chapter V, any ordinary excess of protein is not injurious to farm animals. (**108**)

326. Quality of protein.—The amounts of digestible protein recommended in the feeding standards for the various classes of stock are based on the assumption that protein of average quality will be furnished. It has been shown in Chapter V that the quality of protein is of much greater importance in the feeding of swine and poultry than for cattle, sheep, or horses. (**112, 127**) The only exception is in the case of very young calves being raised on a minimum amount of milk. In feeding swine and poultry it is necessary to give fully as much attention to the *quality* of protein in the ration as to the *amount*.

Information on the quality of the protein in various feeds is presented in Chapter V and in the discussions of the individual feeds in Part II. Full consideration has been given to the importance of proper quality of protein in the rations suggested for the various classes of stock in Appendix Table VII and in the chapters of Part III.

327. Suitability of feeds; palatability.—The feeds selected for any animal should be such that they will not injure its health or impair the product yielded. Feeds which are suited to one class of animals may not be suited to others. Again, a given feed may give satisfactory results when combined with certain feeds, yet in other combinations it may be unsatisfactory. Detailed information is given in Part II concerning the value and use of the many feeding stuffs for the various classes of stock. One can readily learn whether any particular feed is suitable for a given class of stock

A RATION WHICH IS GOOD, BUT LACKS SUCCULENCE

This ration of 25 lbs. good-quality red clover hay, 3 lbs. ground corn, 2.5 lbs. ground oats, and 2 lbs. wheat bran furnishes no more total digestible nutrients than the previous one, but it will produce more milk, because clover is far superior to late-cut timothy hay as a roughage. Only 7.5 lbs. concentrates are needed in this ration. (From Wisconsin Station.)

by consulting the index to find the pages where information about it is given.

The palatability of the ration is important in feeding livestock for production. The wise farmer will utilize feeds of low palatability chiefly for animals which are being merely maintained, and will feed milk cows, growing and fattening animals, and horses or mules at hard work rations made up mostly of well-liked feeds.

Some concentrates, such as malt sprouts and distillers dried grains, which may not be relished when fed alone, are entirely satisfactory if mixed with better-liked feeds. Similarly, if such low-grade roughage as straw is combined with good hay that provides plenty of vitamins, a limited amount can even be fed to dairy cows or to fattening cattle and sheep.

In this country it is not usually ad-

visable to use very low-grade roughage for stock being fed for production, except in emergency. However, in Europe such roughage as straw is often chopped and mixed with the concentrates, the mass being moistened and allowed to stand for a few hours, until the roughage becomes softer and more palatable.

Livestock will usually yield the maximum amount of product only on rations made up entirely or chiefly of palatable feeds. However, it should be borne in mind that an important function of our farm animals is to convert into useful products materials that would otherwise be wasted.

328. Cost of the ration.—The most important factor of all for the farmer who must depend on the profits from his stock for his income, is the cost of the ration. In securing a ration which provides the nutrients called for by the standards and meets the other conditions previously discussed lies a great opportunity for exercising foresight and business judgment.

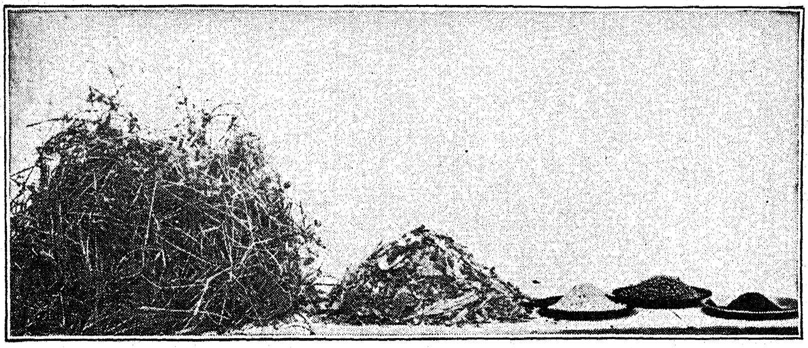
The wise stockman will consider the requirements of his animals in planning his crop rotations. Through the use of farm-grown grain, legume hay, and such cheap succulence as silage from corn or the sorghums, or from hay crops, it is possible in most sections of the country to go far toward providing a well-balanced, economical ration. Methods of determining which feeds are most economical are described in the following chapter.

III. Feeding Standards

329. Early feeding standards.—The first feeding standards based on the digestible nutrients in feeds were presented by Wolff, a German scientist, in 1864. The Wolff standards were modified somewhat in 1896 by Lehmann, another German scientist, as there was then further information concerning the nutritive requirements of livestock. These standards, known as the Wolff-Lehmann feeding standards, were widely used for many years in Europe and also in America in computing balanced rations for livestock. They have been superseded by modern standards.

Feeding standards based on net energy were presented in 1907 by Kellner in Germany[1] and in 1917 by Armsby in this country.[2] It has been explained in Chapter III that the Kellner standards were expressed in starch values, while the Armsby standards were stated in therms of net energy.

In both the Kellner and the Armsby



An Excellent and Economical Ration for Milk Production

This ration of 12 lbs. good-quality red clover hay, 36 lbs. well-eared corn silage, 3 lbs. ground corn, 1.5 lbs. wheat bran, and 2.25 lbs. cottonseed meal is far superior to the first ration and even better than the second. The feeds are all palatable and suitable for dairy cows, and the silage provides succulence. Only 6.75 lbs. of concentrates are needed with the good clover hay and the well-eared corn silage, to furnish as much total digestible nutrients as in the first ration, which has 11.5 lbs. concentrates. (From Wisconsin Station.)

standards the protein recommendations were stated in terms of digestible true protein, instead of digestible crude protein. These standards did not therefore credit the simpler nitrogenous substances in feeds with any value as a substitute for proteins. This point of view has now generally been discarded, as has been mentioned previously. (18) It is therefore much preferable to express the protein requirements of animals in terms of digestible protein (digestible crude protein), as is done in most of the recent feeding standards used in this country.

330. Later feeding standards.—Several different feeding standards for dairy cows have been presented by various scientists, including Haecker, Eckles, Savage, Forbes, Ellett and associates, Möllgaard, Brody, Gaines, and Baker. Lack of space does not permit a discussion of the recommendations in these various standards. However, it is of especial interest to note that Haecker was apparently the first to recognize in his standards that the amount of nutrients a cow requires depends not only on the amount of milk she produces, but also on its richness in fat. The Scandinavian feed unit system has been discussed in Chapter III. (84)

Standards for certain other classes of stock have also been prepared by various scientists. These are mentioned in the chapters of Part III in which the nutrient requirements of the various classes of stock are considered.

Fraps of the Texas Station presented some years ago feeding standards expressed in terms of dry matter, digestible crude protein, and productive value, stated in therms of net energy.[3] These productive values are thus given in the same terms as Armsby's net-energy values.

Recently the National Research Council has published a series of reports, prepared by special committees, which state the amounts of nutrients advised for the various classes of farm animals.[4] The recommendations for the various classes of stock are discussed in the respective chapters of Part III of this volume.

331. The Morrison feeding standards.—Until 1915 the old Wolff-Lehmann feeding standards were used more commonly in the United States than any others, except for dairy cows. In computing rations for milk production, these German standards had been largely replaced by the more accurate American standards, especially by the Haecker standards, the Savage standards, and the Eckles standards. For other classes of stock the Wolff-Lehmann standards were commonly used, although they advised larger amounts of protein than necessary and were not well adapted to American conditions.

At that time the need for modern standards for the various classes of stock was deeply impressed upon the author of this volume. For example, he found that certain companies which annually fattened thousands of cattle and sheep were carefully computing rations with these out-of-date standards. In order to balance the rations according to these standards, they were spending large sums of money for entirely unnecessary amounts of protein supplements, thus considerably reducing their profits.

Neither the Kellner nor the Armsby feeding standards had been widely adopted in this country, for instructors and farmers seemed to prefer standards based on digestible nutrients instead of energy values. The author therefore endeavored to combine in one set of standards what seemed in his judgment to be the best guides available in the computation of rations for the various classes of stock. These standards were first presented in the fifteenth edition of *Feeds and Feeding*, published in 1915, and were then called the "Modified Wolff-Lehmann Standards." They soon came to be known as the Morrison feeding standards.

To lessen the work of computing rations, the standards were expressed in terms of dry matter, digestible protein, and total digestible nutrients, instead of giving separate recommendations for digestible carbohydrates and for digestible fat, as in the Wolff-Lehmann standards. Also, for the reasons stated previously, in

each recommendation in the standards, there was a range in the amounts of dry matter, digestible protein, and total digestible nutrients advised, instead of only one figure being given.

In order to incorporate the results of later investigations, extensive changes were made in the standards in 1936, and the revised recommendations were published in the 20th edition of *Feeds and Feeding*. For those who desired to use net-energy values instead of total digestible nutrients in computing rations, a column was also added which stated the net-energy allowances advised, expressed in therms.

Based upon the further information then available concerning the nutrient requirements of farm animals, extensive changes were made in the standards presented in the 21st edition of *Feeds and Feeding*, published in 1948, and additional changes have been made in the standards given in the present edition. Recommended allowances are now given for calcium, phosphorus, and carotene.

In revising the standards the author has given careful consideration to all recent publications concerning the nutrient requirements of the various classes of livestock. Of especial help in making the revisions have been the reports published by the National Research Council, which have been mentioned previously. In these reports no range is given in the amounts of nutrients recommended for a particular class of animals. In other words, only one figure is given for digestible protein or for total digestible nutrients. For the reasons stated previously, the author prefers to give a range in the amounts of nutrients advised for each class of animal.

Also, in certain of these reports, the total amounts of feed advised are stated in terms of "air-dry feed" instead of in terms of dry matter. Since the moisture content of dry roughage varies considerably in various regions, depending on the humidity of the air, the author prefers to express recommendations in terms of dry matter.

332. Computing rations according to the Morrison standards.—The method of computing rations based on the digestible nutrient recommendations in the Morrison standards has been fully described in the first part of this chapter. In computing rations according to total digestible nutrients, one should entirely disregard the net energy figures which are given in the last column of the various pages of Appendix Table III. He should use the recommendations given for dry matter, digestible protein, and total digestible nutrients, and should consult Appendix Table I to find the corresponding composition of the various feeding stuffs.

However, if one desires to compute rations according to the net energy system, he should disregard the recommended allowances of total digestible nutrients, and should use instead the net energy values shown in the last column of figures. The estimated net energy values of the most important feeds, for use in this method of computing rations, are stated in Appendix Table II. This table also gives the percentages of dry matter and of digestible protein in these feeds.

Except for the difference in the figures used, the method of computing a ration according to the net energy system is the same as when total digestible nutrients are used. It is therefore not necessary to present an example of the use of this method.

QUESTIONS

1. What are feeding standards?
2. Compute a ration according to the Morrison feeding standards for wintering a yearling dairy heifer weighing 700 lbs. In this and the following problem use feeds available in your locality and find the cost of the ration.
3. Compute a ration according to the Morrison feeding standards for 1,200-lb. dairy cows producing an average of 40 lbs. of milk containing 3.5 per cent fat daily. Determine first the necessary percentage of digestible protein in the concentrate mixture to feed with the roughages you select, using the method shown in Article 321. Then work out a formula for a satisfactory concentrate mixture, containing this percentage of digestible protein. Finally,

compute the dry matter, the digestible protein and the total digestible nutrients in the entire ration, to see whether or not it meets the requirements.

4. If you wished to use a good commercial dairy feed for these cows, approximately what percentage of total protein should it contain?
5. What guide do the Morrison feeding standards furnish as to the proper proportion of roughages and concentrates for a particular class of stock?
6. What factors not included in the recommendations of feeding standards must be considered in computing efficient rations for stock?
7. Why have the Wolff-Lehmann feeding standards been superseded by other feeding standards?
8. In what terms are the nutrient requirements expressed in the Armsby feeding standards; in the Kellner feeding standards?
9. What important advance did Haecker make in feeding standards for dairy cows?
10. In what terms are the nutrient requirements of livestock expressed in the Morrison feeding standards?
11. Why is a range indicated in the recommendations given in these standards for each class of stock, instead of only one figure being given for dry matter, digestible protein, and total digestible nutrients, respectively?

REFERENCES

1. Kellner, Ernährung der landwirtschaftlichen Nutztiere, 1907.
2. Armsby, The Nutrition of Farm Animals, 1917.
3. Fraps, Tex. Bul. 461.
4. National Research Council, U.S., Recommended Nutrient Allowances for Domestic Animals: I, Poultry, revised 1954; II, Swine, revised 1953; III, Dairy Cattle, revised 1950; IV, Beef Cattle, 1945; V, Sheep, revised 1949; VI, Horses, 1949; VII, Foxes and Minks, 1953.

CHAPTER XII

ECONOMY IN FEEDING LIVESTOCK

I. Selecting Economical Rations

333. Providing efficient rations at least expense.—One farmer often secures much greater net returns from his livestock than does a neighbor, because he gives more thought to the selection of rations that are not only well balanced but also as economical as possible.

First of all, he grows those crops which have the highest feeding value. He also plans his crop rotations so that he has an abundance of high-quality hay and other roughage for winter feeding and excellent pasture throughout the growing season. If possible, he raises plenty of legume forage crops, so that he will not need to buy large amounts of protein supplements. Finally, in buying protein supplements or other feeds, he uses good judgment in selecting those which are most economical under his local conditions.

334. Guides in selecting economical rations.—It often takes careful study to find which of several available feeds are actually most economical. This is because the market price of the various feeds may not be a guide to their real feeding value. For example, one year there may be a short oat crop in this country, but a good crop of corn. This will make oats unusually expensive in comparison with corn. The next year the conditions may be reversed, and oats will then be an economical feed. Similarly, the relative prices of the various protein supplements vary considerably from year to year, and sometimes there are wide changes in the relative prices of feeds even during a single year.

To secure the most profit from livestock, it is necessary to give careful attention to the changes in feed prices. One should not get into the habit of feeding the same combination of feeds year after year, regardless of whether these feeds are cheap or costly. Experiments have shown that there is no one best ration for any class of stock. Therefore when feed prices change decidedly, one should make whatever changes are necessary in his rations to take advantage of the new conditions.

To aid stockmen in selecting rations that will be economical under different conditions, there are given in Appendix Table VII a considerable number of balanced rations for the various classes of animals. Any of these should give excellent results when composed of good-quality feeds and fed to thrifty animals. Many additional suggestions will be found in the chapters of Part III.

335. Determining which feeds are actually cheapest.—It has been emphasized previously in Chapter III that the best guide to the relative values of different feeds for any class of stock is provided by the results of actual feeding experiments with the same class of animals. (58–59) The statements made in later chapters concerning the values of the various feeds are therefore based chiefly upon extensive studies made by the author of the results of such experiments.

As yet, the relative values of only certain of the most important feeds have been determined by means of feeding experiments with the various classes of stock. For other feeds we must base our comparisons on their content of digestible nutrients or net energy and on the general information about their usefulness for the particular kind of animal.

One method of comparing the economy of feeds is to compute the cost per pound of total digestible nutrients in each feed. This shows which feeds supply total digestible nutrients at least expense. It is a correct method of compar-

ing the values of feeds when protein-rich feeds cost no more than those rich in other digestible nutrients.

However, in most parts of the United States feeds that are rich in protein generally cost more than those which are low in protein but rich in carbohydrates. Digestible protein then has a greater value per pound than digestible carbohydrates. Under such conditions some method should be used which takes into account not only the amounts of total digestible nutrients but also the amounts of digestible protein in the various feeds.

Sometimes the method is used of computing for each feed not only the cost per pound of total digestible nutrients, but also the cost per pound of digestible protein. However, even with this information, it is often difficult to decide which feeds are most economical. For example, one protein supplement may furnish digestible protein at the least cost, while another is a cheaper source of total digestible nutrients. Considerable experience is necessary to balance one factor against the other in estimating the actual relative economy of the two feeds.

Another method is to place a definite price on each pound of total digestible nutrients and an additional value on each pound of digestible protein there is in the feed.[1] These prices are determined from the market price of a common or base carbohydrate-rich feed, such as corn grain, and the price of a common protein supplement. Tables can be worked out on this basis which show the relative money values of various feeds. However, any such table can be used only so long as the base feeds do not change in price. The method therefore has only limited usefulness.

336. The Petersen method of valuing feeds.—Petersen of the Minnesota Station devised an ingenious method which can be used to determine the relative values of various feeds even when the prices of the base feeds change decidedly.[2] He took corn and cottonseed meal as the base feeds, since corn is the most common carbohydrate-rich concentrate in this country and cottonseed meal was then the most important high-protein supplement. However, other base feeds may be used in the same manner. Since soybean oil meal has now become the most important protein supplement in the United States, let us take it as the base protein-rich feed in our discussion of this method.

It is evident that whenever protein-rich feeds cost more than carbohydrate-rich feeds, as is usually the case, then the actual relative value of any other feed will depend partly on the price of the standard or base carbohydrate-rich feed and partly on the price of the base protein-rich feed. Two factors are therefore computed for each feed to be valued. One of these, called the "constant for corn," shows the extent to which the price of corn per ton affects the value of the given feed. The other factor, called the "constant for soybean oil meal," shows the extent to which the price of soybean oil meal per ton affects the value of the particular feed in question.

Constants of this kind for the most important feeds are given in Appendix Table II. These have been computed from the estimated net-energy value and the digestible protein content of each feed, which values are also given in this same table. The net-energy values of the various feeds have been used in computing these factors, instead of the content of total digestible nutrients, because of the reasons stated in Chapter III. (77) In the opinion of the author, net-energy values provide a more accurate basis than do total digestible nutrients for comparing the values of various feeds for productive purposes. This is especially true when one wishes to compare a concentrate that has considerable fiber with one which is low in fiber and high in digestibility and productive value. The difference is even greater in comparing a high-grade concentrate with hay or other dry roughage.

In computing these factors, solvent-process soybean oil meal has been taken as the base protein-rich feed, because of its importance. Dent corn of Federal Grade No. 2 has been taken as the base carbohydrate-rich feed.

To illustrate the method of using these constants, let us compute the value of corn gluten feed for dairy cows as a source of digestible protein and of net energy, in comparison with ground corn (Grade No. 2) at $60.00 per ton and soybean oil meal at $80.00 per ton.

In the case of feeds which apparently have a higher relative value for dairy cows than for meat production, separate net energy values and feed evaluation constants for dairy cows are given in Appendix Table II. This is the case with corn gluten feed.

By referring to the table, we find that the "Constant for corn" of corn gluten feed for dairy cows is 0.456, and the "Constant for soybean oil meal" is 0.434. To find the value of corn gluten feed, we multiply the price of corn by 0.456, the "Constant for corn;" and next we multiply the price of soybean oil meal by 0.434, the "Constant for soybean oil meal;" and finally we add the products. This gives us $62.08 as the value of corn gluten feed for dairy cows, in comparison with corn and soybean oil meal at the particular prices stated in this example.

337. Graphs for finding the relative values of feeds.—In order to make these computations unnecessary, Petersen has also devised convenient graphs, from which the relative values of feeds can be easily read, with corn and cottonseed meal at any particular prices. Such graphs have distinct advantages over the use of the "constants." First, no computation whatsoever is required. Second, if some other protein-rich feed is decidedly cheaper than cottonseed meal or whatever protein supplement is used as the base feed, it may be taken as the standard protein-rich feed in using the graphs. Likewise, barley or one of the other small grains may be used as the standard low-protein feed, if one of these grains is cheaper or more available locally than corn.

To be used accurately, graphs of this kind must be of larger size than can be included in such a volume as this. Also, only a few feeds can be given in each graph, as otherwise the lines for various feeds would fall too close together to be legible.

It has been pointed out previously that when protein-rich feeds cost no more or even less than those low in protein, the amount of total digestible nutrients (or net energy) should be used as the basis for determining the relative values of various feeds. To make such comparisons possible without any need for computations, graphs have also been devised from which the relative values of the important feeds can be determined at a glance, taking as a standard of comparison one of these feeds at any particular price.

338. A comparison of corn-belt feeds for dairy cows.—To illustrate the manner in which the relative economy of different feeds may be determined by using the constants in Appendix Table II, let us assume that a dairyman in the corn belt has plenty of the following home-grown grains: Shelled corn (Grade No. 2), worth $1.45 a bushel, or $51.79 a ton, on the farm; oats, worth $.86 a bushel, or $53.75 a ton; and barley of good brewing grade, worth $1.33 per bushel, or $55.42 a ton. He wishes to feed his cows the grain which is cheapest, considering its feeding value, and to sell that which is highest priced.

It will cost about $3.50 a ton to grind these grains, as should be done for dairy cows. This will make the farm price of ground corn $55.29 a ton; of ground oats, $57.23 a ton; and of ground barley, $58.92 a ton.

To balance the ration the following protein supplements are available on the local market: Corn gluten feed at $60.00 per ton; cottonseed meal (41 per cent protein grade), $70.00 per ton; distillers dried corn grains (without solubles), $67.00 per ton; linseed meal, $75.00 per ton; soybean oil meal (solvent process), $75.00 per ton; and wheat bran, $50.00 per ton. Cane molasses is also available at $48.00 per ton in barrels. If it could be secured locally from a tank car, the price would be much lower.

Limited amounts of these feeds can be hauled home on return trips from town without much of an additional

cartage expense. It is not assumed that these prices represent average conditions in any section of this country, but they are merely taken to illustrate the manner in which the relative economy of various feeds may be compared.

We will assume that this farmer has for his cows plenty of good mixed clover-and-timothy hay containing one-third to one-half clover, and in addition has enough corn silage to feed throughout the winter. With such roughage, a concentrate or "grain" mixture containing about 18 per cent total protein or 14.5 per cent digestible protein will provide enough protein for good production. (See Articles **323** and **1017**, and also the example rations in Appendix Table VII.) Let us therefore compute an economical concentrate mixture which will supply about 14.5 per cent of digestible protein.

First, we will compute from the constants in Appendix Table II the values per ton of the various feeds, taking corn and soybean oil meal as the base feeds, or the standards of comparison. We will set these values down in tabular form, along with the market prices of the various feeds. We will then set down for each feed the amount by which its computed value per ton is greater or less than the market price. This will give us the following table.

The table shows that with feeds at these particular prices, wheat bran is the only other concentrate that supplies digestible protein and net energy as cheaply as do corn and soybean oil meal. Ground barley is worth for feeding $1.74 less per ton than the farm price. It will therefore be most economical to feed ground corn as the chief grain and to sell the barley.

If fed as the chief grain to dairy cows, ground oats is worth considerably less than the current price. However, when not over 25 per cent of ground oats is included in the mixture, oats has a higher value and is nearly as economical as ground corn. This higher value for oats when forming not more than 25 per cent of the concentrate mixture is based upon numerous experiments which are summarized in Chapter XX.

Cane molasses is slightly less economical at the price of $48.00 per ton than ground corn at the farm price of $55.29 per ton. It should therefore be used only if needed to increase the palatability of a ration that might otherwise not be well liked.

339. Choosing an economical concentrate mixture.—This dairyman wishes to use a concentrate mixture made up as largely as possible of his home-grown grains. From the standpoint of economy

Comparison of economy of various concentrates at prices stated

	Price of feed per ton Dollars	Value of feed per ton Dollars	Difference per ton between price and value Dollars
Farm grains			
Barley, ground (*for dairy cows*)	58.92	57.18	−1.74
Corn, dent, ground	55.29	55.29	....
Oats, ground, as chief grain	57.23	51.69	−5.54
Oats, ground, not over 25% of concentrates	57.23	56.74	−0.49
Purchased concentrates			
Corn gluten feed (*for dairy cows*)	60.00	57.76	−2.24
Cottonseed meal, 41% protein	70.00	65.06	−4.94
Distillers dried corn grains, without solubles	67.00	64.91	−2.09
Linseed meal, expeller or hydraulic process, 32% protein grade	75.00	66.40	−8.60
Molasses, cane, not over 10% of concentrates	48.00	45.82	−2.18
Soybean oil meal, solvent process	75.00	75.00	....
Wheat bran	50.00	50.57	+0.57

he will therefore use ground corn as the chief part of the mixture.

When forming not over 25 per cent of the concentrates, ground oats is nearly as economical as ground corn, and oats will add bulk to the mixture. At the prices stated, wheat bran is a cheap feed, and a little bran will add bulk and variety. (1071)

At these prices the most economical concentrate mixture will be a combination of ground corn, ground oats, soybean oil meal, and wheat bran. A little figuring will show us that a mixture of 500 lbs. ground corn, 210 lbs. ground oats, 190 lbs. soybean oil meal, and 100 lbs. wheat bran will supply the desired percentage of digestible protein. This is shown in the following table:

An economical concentrate mixture with feeds at the prices stated

	Digestible protein Lbs.	Cost Dollars
Corn, ground, 500 lbs.	33.5	13.82
Oats, ground, 210 lbs.	19.7	6.01
Soybean oil meal, 190 lbs.	79.8	7.13
Wheat bran, 100 lbs.	13.3	2.50
Total in 1,000 lbs.	146.3	29.46
Per 100 lbs.	14.6	2.95

This mixture will be very economical under these particular conditions, and it should produce excellent results, for it is made up of feeds of high nutritive value and feeds that are well liked by dairy cows. Some dairymen might prefer a concentrate mixture with greater variety, containing a greater number of different feeds. However, at these particular prices other feeds could not be included in the mixture without somewhat reducing the economy.

340. Changing the mixture to meet changed feed prices.—To show how a ration should be modified to meet changed feed prices, let us assume that the next year the prices for some of the feeds have changed as shown in the following table:

Effect of changed prices on economy of various feeds

	Price of feed per ton Dollars	Value of feed per ton Dollars	Difference per ton between price and value Dollars
Farm grains			
Barley, ground	53.00	57.18	+4.18
Corn, dent, ground	55.29	55.29	....
Oats, ground, not over 25% of concentrates	54.00	56.74	+2.74
Purchased concentrates			
Corn gluten feed	52.00	57.76	+5.76
Cottonseed meal 41% protein	66.00	65.06	—0.94
Distillers dried corn grains, without solubles	67.00	64.91	—2.09
Linseed meal, expeller or hydraulic process, 32% protein grade	72.00	66.40	—5.60
Molasses, cane, not over 10% of concentrates	47.00	45.82	—1.18
Soybean oil meal	75.00	75.00	....
Wheat bran	49.00	50.57	+1.57

Corn and soybean oil meal have remained at the same prices as in the first example, but the prices of barley and oats have declined. These grains are now more economical than corn for dairy cows. The price of corn gluten feed also has fallen, so that it is now the most economical protein supplement. Wheat bran is also low in price in comparison with other feeds. The other protein supplements are slightly less economical than corn gluten feed, wheat bran, and soybean oil meal. Molasses has declined slightly in price, but does not supply net energy as economically as do the grains.

With feeds at these changed prices, the cheapest concentrate mixture would have corn gluten feed as the only protein supplement. For cows of ordinary productive capacity, a mixture consisting of only ground barley, ground oats,

and corn gluten feed would be fairly satisfactory when fed along with good roughage. This is because the quality or kind of protein is not important for dairy cows that are fed plenty of good roughage. (1018)

However, most dairymen would prefer to use a concentrate mixture with greater variety and having some other protein supplement in addition to corn gluten feed. Let us therefore include some soybean oil meal in the mixture. It ranks next to corn gluten feed in economy at these prices, and it furnishes high-quality protein.

At these prices an excellent and economical mixture would be: Ground barley, 430 lbs.; ground oats, 200 lbs.; corn gluten feed, 200 lbs.; soybean oil meal, 70 lbs.; and wheat bran, 100 lbs.

These two examples well show that no particular combination of feeds should be used year after year, regardless of the changes in feed prices. On the contrary, the ration should be modified whenever necessary to adapt it to changed price conditions.

341. Relative economy of feeds when protein is cheap.—In the preceding examples protein-rich feeds have been more expensive than those rich in carbohydrates. Protein has therefore had an additional value beyond the amount of total digestible nutrients it furnishes. However, this is not always the case.

For example, in the cotton belt cottonseed meal is often lower in price per ton than farm grain. Also, in the alfalfa districts of the West alfalfa hay is frequently so cheap that it supplies total digestible nutrients at much less cost than do the grains or other carbohydrate-rich feeds. Even in the northeastern states, protein-rich concentrates are sometimes decidedly lower in price than the farm grains.

Under all such conditions, the values of various feeds will depend on the amounts of total digestible nutrients or of net energy that they furnish, and will not be affected by the amounts of digestible protein they contain. To compare feeds on the basis of net energy one should use the factors in the last column of figures in Appendix Table II. The method of using these factors is explained in the paragraphs that precede the table.

342. Limitations in comparisons based on digestible nutrients.—These methods of comparing the relative values of feed are much better adapted to comparisons of various concentrates than to comparisons of roughages. This is because such factors as palatability and the content of vitamins and minerals are often of great importance in determining the actual value of roughage.

Thus, a valuation on the basis of digestible nutrients, or on the basis of net energy, may not measure at all the actual difference in feeding value between well-cured, green-colored hay and hay that is weathered and bleached. The poor hay will, of course be considerably lower in digestible nutrients than the good hay. However, unless the stock get plenty of vitamin A value from some other source, the poor hay may be worth much less than is indicated by its content of digestible nutrients, due to the deficiency of this vitamin.

Also, one class of stock may have a much greater need than another class of animals for vitamins or minerals that the particular feed furnishes. For example, a limited amount of choice alfalfa or other legume hay has an especially high value, not measured by its content of digestible nutrients, as a source of vitamins A and D in the winter feeding of pigs in the northern states. Similarly, excellent hay is nearly indispensable in the raising of dairy calves. On the other hand, idle horses and beef breeding cows can be wintered successfully on roughage of rather inferior quality.

While comparisons of various roughages can be made by using the constants in Appendix Table II, it must be remembered that such a method of evaluation may have great shortcomings for these feeds. A much safer basis for valuing roughage is provided by the information presented in Part II concerning the value and usefulness of the various roughages for the different classes of stock.

Another limitation of this method of comparing the economy of various feeds

is that it does not take into consideration the *quality* of the protein in the different feeds.

Protein of high quality is especially important for swine, for poultry, and for dairy calves being raised on milk substitutes. Therefore, feeds that furnish protein of excellent quality, such as meat scrap, tankage, and fish meal, have a much higher relative value for these animals than for other classes of stock.

Other examples of the considerable differences in the relative values of certain feeds for various classes of stock have been given in Chapter III. (59) These differences show that, where the information is available, the results of feeding experiments are the most reliable guide to the value of any feed for a particular class of stock. Such information is given in the chapters of Part II.

II. Adapting Systems of Feeding to Local Conditions

343. Amount of protein to supply.—In the Morrison feeding standards a range is indicated in the amounts of protein which are advised for the various classes of farm animals. When protein-rich feeds cost but little or no more than those low in protein, it is well to feed as much protein as is indicated by the higher figures. On the other hand, when corn or the other grains are relatively cheap, it may be more economical to feed no more protein than is called for by the lower figures. Rarely is it advisable to feed decidedly less protein than shown in the lower figures.

Whether or not to add a protein supplement to certain rations will depend on the relative price of such supplements in comparison with the prices of the farm grains. For example, it is shown in Chapters XXVIII and XXX that corn and legume hay alone make a fairly well-balanced ration for fattening cattle or fattening lambs. However, the gains are usually slightly increased and a higher finish is secured when a small allowance of some suitable protein supplement is added to the ration. Whether such an addition will be profitable or not depends on the relative price of the supplement and on whether the market will pay an appreciably better price for the more highly-finished animal.

When protein-rich feeds supply nutrients more cheaply than those low in protein, as is often the case in the cotton belt and in the alfalfa districts of the West, it will be economical to feed more protein than the amounts stated in the standards.

344. Proportion of roughages to concentrates.—To meet the recommendations of the feeding standards for good milk cows and for fattening cattle and sheep, fairly liberal amounts of concentrates are required. This is because rations rich in digestible nutrients are needed for a high yield or for rapid fattening.

Unless grain or other concentrates are unusually expensive in comparison with roughages, it is generally advisable to feed such stock fully as much concentrates as called for by the higher set of total-digestible-nutrient recommendations in the feeding standards. On the other hand, when roughage is very cheap, it may be most profitable to feed only a small amount of concentrates.

Young cattle and lambs cannot be made fat enough to meet the demands of the large markets on harvested roughage alone, even if it is of excellent quality. On the other hand, little or no premium is paid on some local markets of the West for animals that have been well fattened by feeding them grain. Under such conditions it may not pay to feed any concentrates in addition to good hay or hay and silage.

With dairy cows much depends on the productive capacity of the cow. Except when concentrates are extremely high in price in comparison with roughages, a cow of good productive capacity will pay for at least a fair allowance of concentrates. On the contrary, the most economical rations for a low-producing cow, when concentrates are very high in price, may be legume hay and silage, with no concentrates whatsoever.

The feeding standards for growing cattle are based upon continuous thrifty

growth, and hence call for the feeding during winter of a small allowance of concentrates, unless a liberal amount of excellent roughage is fed. The breeder of pure-bred animals who wishes to develop the best there is in his young stock will feed sufficient concentrates to keep them growing rapidly. On the other hand, the western rancher may find it most profitable to carry young stock through the winter on roughage alone, or with but a very small allowance of concentrates. Thus fed, they will gain in frame and, though losing in flesh, will be thrifty enough in the spring to make good gains on the cheap pasturage.

It is a matter of great financial importance in stock farming to make a wise decision concerning the amounts of concentrates to feed the different classes of stock under varied conditions. This matter is therefore given special consideration in Part III of this volume.

345. When roughage is scarce.—Occasionally there is a serious shortage of roughage in some part of the country, because of severe drouth. Hay and other roughage may then be so high in price that digestible nutrients in roughages will be much more expensive than digestible nutrients in grain and other concentrates.

Under such conditions, it is most economical to increase the proportion of concentrates somewhat and to feed no more roughage than is necessary to provide adequate bulk in the ration and a sufficient supply of vitamins.

However, enough roughage must be fed to meet the needs of the particular animals. It is shown in Chapter XXV that in experiments in which dairy cows have been fed a very small amount of roughage, especially chopped or ground hay, they have often gone off feed, and the milk yield and fat percentage have dropped greatly.

BEEF STEERS ON FULL-FEED IN A CORN-BELT FEED LOT

On this corn-belt farm practically all the land is suitable for tillage and corn is the main crop. During the winter, western feeder cattle are fattened in dry lot on a full feed of corn grain, plus corn silage, legume hay, and a small allowance of protein supplement. A maximum amount of corn grain is thus utilized on the farm.

346. Finish animals to meet demands of the market.—The wise stockman will keep in close touch with the demands of the market and adjust his feeding operations accordingly. If the market pays a sufficient premium for thoroughly-fattened animals, he will fat-

ten his stock well before marketing them. On the other hand, on local markets which pay no more for a well-finished carcass than for one carrying less fat, it will not pay to prolong the fattening period or to feed as much concentrates as are necessary to make the animals thoroughly fat.

347. Seasonal trends in prices of feeds.—A stockman who is a close observer of the usual trends in prices of grains and other feeds can sometimes save money by buying a supply at the time of year when the particular feed is generally lower in price than at other seasons.

For example, the grains are generally lower in price at harvest time, when the marketings are heaviest.[3] The price tends to rise during the year, until the effects of the new crop begin to be felt. Wheat bran is apt to be lower in price in the fall than at other seasons.

348. Efficiency in the use of labor.—Since man labor forms a considerable part of the costs in livestock production, every effort should be made to use labor as efficiently as is possible. As is shown in the chapters of Part III, the number of hours of labor spent in feeding and caring for stock can often be greatly reduced by careful planning. (1101)

To save labor, stables and feed lots should be arranged so that the minimum amount of labor and walking about is required. Much labor can be saved by convenient tools and equipment, such as feed carts and a water system in the barn with individual drinking cups for stall-fed animals. Much time in caring for dairy cows can be saved by the adoption of the rapid-milking method. (**1093**)

BEEF HERD ON PASTURE UNSUITED FOR TILLAGE

On this farm there is considerable land which is too rough for tillage. This provides pasturage for a breeding herd of beef cattle. The cattle are wintered on hay and other roughage, and grain is used only for fattening the young cattle for market.

349. Adapt type of farming to local conditions.—It is outside the field of this volume to discuss in detail the many factors which the stockman should take into consideration in deciding the type of livestock farming in which to engage and the systems and methods to follow. The farm operations and practices should always be suited to local conditions, and should be based upon the prices of land and labor, the nearness to market, and the available crops.

For example, the beef producer on high-priced land in the eastern part of

the corn belt will often crowd his calves to rapid growth on a heavy allowance of grain and fatten them as baby beeves. Perhaps he will raise no cattle, but fatten feeder steers from the western ranges on a liberal allowance of corn.

On the other hand, in the West where pasture is cheap compared with grain, the rancher will usually follow a much less intensive system of beef production. Even during the winter his breeding herd will be maintained as largely as possible on the range and will be fed harvested feeds only when the range forage is covered by snow. Instead of fattening his steers for market, the rancher will commonly sell them in the fall as feeder cattle, to be shipped to the districts where grain is cheaper. When he does fatten cattle, he will feed them chiefly on roughage, with only a limited amount of grain.

Dairymen producing market milk on high-priced land near large cities often use only a small acreage of land for pasture, but instead rely largely on corn silage or soiling crops for roughage during the summer. They often buy most of the concentrates for their cows, including grain as well as protein supplements. They do this because grain can be grown on land farther from market and shipped in at a lower price than the cost of raising it on their own farms. Sometimes they even buy a considerable part of the hay they feed in winter.

Such a system would be decidedly uneconomical for the dairyman remote from the large markets, whose milk is used in the manufacture of butter or cheese. With him land is less expensive than labor. He must therefore adopt a less intensive system of dairying, in which the herd is maintained chiefly on pasture in summer, and in which just as much as possible of the feed for the remainder of the year is produced on the farm.

III. Economy of Food Production by Various Animals

350. Proportion of animal food in the human diet.—In areas of the world where the density of population presses most upon the food supply, foods of animal origin form but a small part of the human diet.[4] In such regions, people must eat all or nearly all the edible food produced on the cultivated fields, and farm animals can have only the forage or other feed that cannot be consumed by man. This is because there is a large loss of energy or heat value in converting into human food the grain or other feed eaten by livestock.

In such parts of the world but few farm animals can be kept in cultivated areas for the primary purpose of producing food for man. Animals are kept for draft or work, perhaps also producing a very limited amount of milk for humans, and they are eaten only when they are no longer efficient work animals. Areas that are unsuited to crop production are grazed by sheep, goats, or cattle, which contribute to the small supply of foods of animal origin. Swine and poultry are kept chiefly as scavengers, living mainly on garbage and other waste products.

According to estimates by Pearson and Harper, grain and grain products make up about 73 per cent, on the dry basis, of the total food consumed by the world's population, and all animal products about 9 per cent.[5] Vegetables and fruits form 12 per cent of the world's human food, and sugar 6 per cent. Included in the animal products are milk and milk products, estimated at 5 per cent on the dry basis, meat at 4 per cent, and fish and eggs each at less than one-half per cent.

The proportion of the total human food that comes from animal sources differs greatly in various regions. In North America it is 25 per cent and in Oceania (over three-fourths of whose population is in Australia and New Zealand) even higher, being 36 per cent. At the other extreme, in Asia foods of animal origin form only 3 per cent of the human diet and in Africa but 4 per cent.

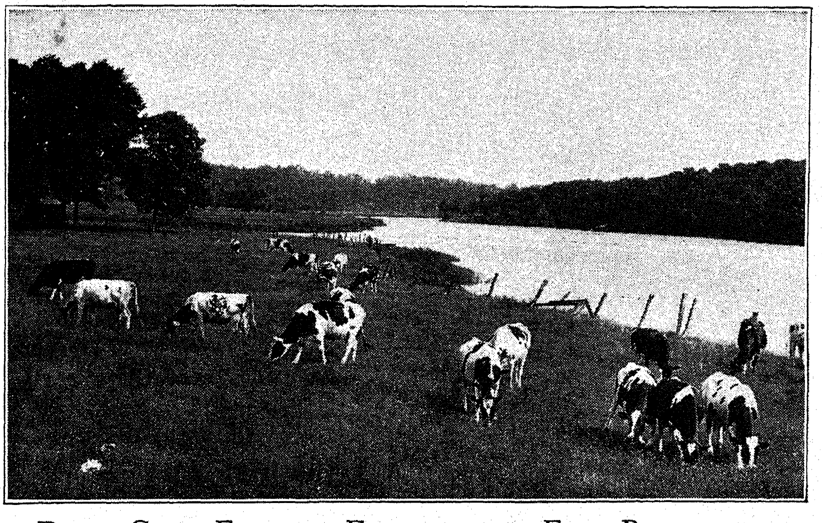
351. Relative efficiency of various animals on energy basis.—Such data lead naturally to a consideration of the relative efficiency of the various farm animals in producing human food, and to a

discussion of the special values in the human diet of foods of animal origin.

Let us first consider the efficiency with which various animals convert the gross energy of the feed they consume into energy in human food. This is the simplest basis for comparison, but all will agree that it is an inadequate measure of the efficiency of farm animals. We do not eat animal products primarily as a source of energy, for we can get energy at a fraction of the cost by eating grain products or such foods as potatoes.

Maynard has estimated that the following average percentages of the gross energy in the feed eaten by various kinds of animals are converted into human food: Pork, 20 per cent; milk (dairy cows), 15 per cent; eggs, 7 per cent; poultry meat, 5 per cent; beef, 4 per cent; lamb, 4 per cent.[5]

The estimates were based on somewhat better than average levels of production. For milk production the estimates were based on an annual yield per cow of 7,000 to 8,000 lbs., which is considerably above the United States average. The estimates for pork were for the period from weaning to slaughter at approximately 230 lbs. live weight. For beef and lamb the estimates were limited to the fattening period in the feed lot because of the impossibility of measuring the feed intake from pasture or range. No credit was given in the estimate for the wool produced by lambs. For egg production the estimate was for an annual production of about 150 eggs per bird. Since these estimates were made, progressive farmers have improved the efficiency of their pork production somewhat by the use of antibiotic and vitamin B_{12} supplements, and the efficiency of poultry meat has been increased by the use of these supplements and also by feeding high-energy rations.



DAIRY COWS EXCEL IN EFFICIENCY OF FOOD PRODUCTION

When due consideration is given to the richness of milk in high-quality protein, calcium, and vitamins, dairy cows are decidedly more efficient than other animals in producing human food.

In these estimates and also in others that have been made, pork production and milk production rank far ahead of other types of animal production, when measured by the percentage of the gross energy of the feed which is converted into edible human food.

In comparing the efficiency of pork production and of milk production, we

must bear in mind that under conditions such as in the United States hogs live chiefly on grain and other concentrated feeds which are high in digestibility and consequently high in net-energy value. On the other hand, only about one-third of the dry weight of the feed of dairy cows usually consists of grain and other concentrates. Two-thirds comes from pasturage, hay, silage, and other roughages, all of which are much lower in digestibility and in net-energy value than the grains.

Measured on the basis of the efficiency with which they convert either digestible nutrients or net energy into human food, dairy cows would rank somewhat above swine. Also, measured on the basis of the calories of human food produced per acre of crop fed, milk production would rank slightly above pork production.

It must be borne in mind that these estimates of the efficiency of milk production are based upon the human consumption of all the food value in milk. When butter is eaten and the skimmilk is used for animal feeding, the efficiency of human food production is, of course, decidedly lower.

In all comparisons of the efficiency of the production of human food by the different classes of farm animals, certain facts must always be remembered. Swine and poultry are direct competitors with man for food, because under our conditions they live chiefly on grain.

In this country dairy cows compete with man for food to a much greater extent than do beef cattle or sheep. This is because our dairying is located almost entirely on land that could be used for the direct production of human food. While dairy cows on many farms utilize pasturage on some areas that could not readily be tilled, such forage forms but a small part of the total feed eaten by our dairy cows.

On the other hand, our beef cattle and sheep are mostly raised on the western ranges or on other grazing land that is unsuited to tillage under present conditions. Here they convert forage that would otherwise be wasted into valuable human food and other products, needed by man, such as wool and hides. Except for the very limited amounts of harvested roughage and of concentrates which may be needed during the winter period, range beef cattle, sheep, and Angora goats do not compete with man for food, or even with dairy cows, swine, and poultry.

352. Relative economy considering other factors.—The chief value of most foods of animal origin lies not in the energy they furnish, but in their high-quality protein and in their content of minerals and vitamins. It is difficult to take all these nutrients into consideration in comparing the economy of various food sources. However, protein can and should certainly be considered, along with energy.

To take both energy and protein into consideration, Jennings has estimated the feed units required by the various farm animals to produce what he calls "a calorie-plus-protein index."[6] In this index the production of 0.15 lb. of protein (a day's allowance for an average person) is given the same weight as the production of 2,600 Calories (which is the daily energy allowance for an average person).

The feed units are approximate estimates of the value of various feeds in comparison with 1 lb. of corn grain as the standard. Hay and other roughages are valued approximately in proportion to their net-energy values. Protein supplements, such as soybean oil meal, are given a considerably higher value than corn grain, although their net-energy values are usually lower, instead of higher, than that of corn grain. These higher values are given to protein supplements because of the higher total feeding value of a protein supplement when properly used to balance a ration low in protein.

Measured on this basis, he estimates that the following amounts of feed units are required for the production of a calorie-plus-protein index of 1.0: Milk production, 6.5; pork production, 9.2; turkey meat, 9.7; eggs, 10.7; chicken meat, 12.0; beef, 41.3; and lamb, 51.7.

These estimates are for average conditions.

It should be noted that on this basis milk production is decidedly more efficient than pork production. Turkeys are rated nearly equal to pigs in efficiency of meat production, and ahead of the efficiency of egg production.

Considering total feed consumed, beef cattle and sheep fall far below the other farm animals in efficiency. However, Jennings also gives similar estimates of the grain and other concentrates, not including pasture, hay, and other roughage, required by the various farm animals to produce a calorie-plus-protein index of 1.0.

On this basis, dairy cows lead, with a requirement of only 1.6 feed units. For other types of livestock production the following amounts of feed units are required in grain and other concentrates: Lamb, 3.2; pork, 8.6; beef, 8.8; turkey meat, 8.8; eggs, 10.1; and chicken meat, 10.9 feed units.

353. Importance of animal foods in the human diet.—Among foods of animal origin, milk production not only ranks first in efficiency of production when both energy and protein are considered, but it also is of especial value in the diet as a source of calcium and vitamin A. Both of these nutrients are needed in very large amounts by children and by pregnant and nursing mothers. Milk is likewise rich in phosphorus, but a deficiency of phosphorus occurs in human diets much less frequently than a lack of calcium or of vitamin A.

Maynard emphasizes that since calcium cannot be supplied adequately by any combination of vegetable foods which our people can be expected to eat, the high content of calcium in milk is of especial importance. One quart of milk a day supplies the full allowance of calcium recommended by the Food and Nutrition Board for a growing child, except during adolescence, and more than is needed by the adult, except for expectant and nursing mothers. It would take 45 eggs to supply as much calcium as is furnished by a quart of milk.

The importance of milk and of all dairy products which include the butterfat, as sources of vitamin A in the human diet is so generally recognized that it needs no discussion. Milk is also rich in riboflavin, and it is a good source of vitamin B_{12} and other B-complex vitamins.

Eggs are important sources of vitamin A value, being three times as rich as milk per unit of total energy. They are also an important source of calcium, are the richest of all animal foods in iron, are high in riboflavin, and are the only important source of vitamin D among natural human foods.

In addition to its high value as a source of excellent quality protein, meat is important in furnishing iron and certain B-complex vitamins, especially niacin. Pork ranks high in thiamine content, and it is estimated that nearly half of the thiamine in the average diet in this country is supplied by animal products.

An important point is that ruminants do not apparently require the B-complex vitamins in their feed, because these vitamins are synthesized in the fermentations which occur normally in the rumen, or paunch. On the other hand, pigs and chickens, like humans, must have an adequate supply in their food.

An exceedingly important quality of most foods of animal origin is their high palatability. Not only do they taste good in themselves, but they also greatly increase the acceptability of other foods. The universal desire of our people for a liberal amount of meat, when they can afford it, was dramatically shown in wartime. When meat supplies became scanty, buyers formed long queues and dissatisfaction and complaint were widespread.

Considering all factors, milk production easily ranks first in importance and efficiency of production, among foods of animal origin. For this reason, every effort was made in Great Britain and other European countries during the war years to keep milk production as near the normal level as possible, and

to restrict severely the concentrated feeds allotted for other classes of farm animals.

From the energy standpoint, pigs would rank next, but considering all factors, second place in efficiency should probably be given to egg production.

From the standpoint of national food economy, the production of beef and lamb also ranks very high, insofar as the meat is produced largely from forage which would not otherwise be utilized.

In considering the place of animal products in our economy, we must bear in mind that farm animals furnish other products. The farm manure they produce is highly important in the maintenance of the fertility of our farms. Other important products, of course, are wool, mohair, hides, by-products for animal feed, and an array of special packing-house by-products.

354. Increasing the production of foods of animal origin.—In considering the place of animal products in our national economy, we must give attention to the possibilities of increasing the supply of these products as our population grows, without decreasing the yield of crops grown for human food.

First of all, the amount and the efficiency of animal production could be very considerably increased if all farmers adopted and carried out the methods now used by the most efficient third. For example, the average milk yield per cow could be increased from the present national average of about 5,630 lbs. to the average in Dairy Herd Improvement Association herds throughout the country, which was 9,363 lbs. in 1954. All that is needed for such an increase is the putting into practice by all farmers of the methods and practices that are now well known, and are practiced by the more progressive farmers. These include well-planned crop rotations, proper fertilization, and good soil management, as well as efficient feeding and breeding of dairy cattle.

To reach the goal of high average milk production, cows must, first of all, be provided with a more abundant supply of roughage of higher quality. This means better pasture, such as that furnished by combinations including such efficient and nutritious pasture crops as alfalfa, Ladino clover, bromegrass, and lespedeza. It also means the production of better hay, curing it efficiently, and feeding it in abundance. In most dairy districts, it will moreover mean the providing of more high-quality silage from corn or the sorghums, or from hay crops ensiled by special methods.

By supplying cows with an abundance of such roughage throughout the year, the amounts of grain and other concentrates required to maintain high milk production can be reduced decidedly. Yet, under our usual conditions, it is essential that good dairy cows be fed sufficient concentrates for a high yield. When they are fed roughage alone, even of excellent quality, the milk yield is greatly reduced.

Such a program of abundant and better roughage for dairy herds should increase, rather than decrease, the supply of grain for human consumption. The fields used in rotation for grain production, with legumes in the rotation, will produce much higher yields than under less efficient cropping methods. Actually, a smaller acreage per cow may be needed to supply ample high-quality pasture and harvested forage than is now needed to furnish a rather scanty amount of mediocre roughage.

It is important to note that the improved roughage feeding of dairy cows, which will increase their production, will also increase the vitamin-A value of milk and butter markedly. In particular, an abundance of high-quality hay and especially of hay-crop silage will maintain a high vitamin-A value in milk in winter, when otherwise it has a lower amount.

The rapid development of artificial insemination of dairy cows has made possible a decided increase in the productive capacity of our cows. Through this means a dairyman can at moderate cost have his cows bred to a bred-for-production sire of a transmitting ability

that has not hitherto been generally available to farmers who do not have large herds.

As our population increases and we need more food, the production of beef and lamb can be considerably increased by converting some of our semi-abandoned hill lands into first-class pastures. There are considerable such areas in the northeastern states and in many sections of the South. Large areas of the cut-over lands of our northern states are also yet undeveloped.

These are but examples of the manner in which the production of foods of animal origin can be increased as our population grows. Similarly, our production of other foods can be greatly increased through fuller utilization of our land resources, improved varieties of crops, increased use of fertilizers, and better soil management.

Even with a considerably greater population, our present dietary standards can not only be maintained but even materially improved, with resulting benefit to the health of our people.

QUESTIONS

1. Using local prices for feeds, see if you can find instances where the market price of a feed does not represent its actual feeding value compared with other feeds which are available.
2. What difficulties are there in comparing the relative economy of various feeds on the basis of the cost per pound of total digestible nutrients and the cost per pound of digestible protein?
3. How is the relative value of a feed determined by the Petersen method?
4. Find the local prices of at least 3 farm grains and 5 protein supplements suitable for dairy cows. Then determine, by using the Petersen method, which of these feeds are actually the cheapest. Finally, work out the most economical concentrate mixture you can that will supply 16.0 per cent digestible protein and be excellent for dairy cows.
5. On what basis should feeds be compared when protein-rich feeds cost no more than those low in protein?
6. Why are comparisons of the values of various roughages, based solely on digestible nutrients or net energy, less reliable than similar comparisons of concentrates?
7. How would you adapt the amount of protein in the ration to local conditions?
8. When would you feed less concentrates than called for in the feeding standards?
9. Under what conditions are beef calves fattened for baby beef?
10. Discuss other ways in which you would adapt the type of farming to local conditions.
11. Compare the proportions of the total human food in various parts of the world which come from animal sources.
12. Discuss the relative efficiency on the energy basis of various farm animals in producing human food.
13. Compare the efficiency of various farm animals in producing human food, when both energy and protein are considered.
14. Discuss the importance of animal foods in the human diet.
15. How can the supply of foods of animal origin be increased in this country, without reducing the production of crops grown for human food?

REFERENCES

1. Hayden, Ohio Cir. 128; Fraps, Tex. Bul. 323, Texas Control Cir. G.
2. Petersen, Jour. Dairy Sci., 15, 1932, pp. 293–297; Petersen, Minn. Exten. Pamphlet 33.
3. Byer and Butz, Ind. Bul. 484; Haag, Mo. Cir. 230; Bennett, N.Y. (Cornell) Memoir 255; Smythe and Hogland, S.D. Bul. 367.
4. Pearson and Harper, The World's Hunger, 1945.
5. Maynard, Jour. Nutr., 32, 1946, pp. 345–360.
6. Jennings, U.S. Dept. Agr. Cir. 670.

PART II

FEEDING STUFFS

CHAPTER XIII

PASTURE AND OTHER FORAGE

I. FACTORS AFFECTING THE VALUE OF FORAGE

355. Importance of pasture and other forage.—Pasture and other forages are considered first in this volume, among all the different feeds, because of their outstanding importance in livestock production. For all classes of stock except swine and poultry, good forage, including abundant pasture, is the foundation of efficient production. Even for swine and poultry, high-quality forage is very important as a source of vitamins, minerals, and protein.

This country has witnessed a striking trend toward "grassland farming" during recent years. This has come about because our farmers have come to appreciate more fully the economy of excellent pasture and hay crops in livestock production, and also their importance in maintaining soil fertility and preventing water and wind erosion. This great change in our agriculture has resulted because of the extensive research on forage production by the experiment stations and the United States Department of Agriculture, and the effective extension work which has convinced farmers of the value to them of the new methods of producing more and far better forage.

The importance of forage crops in the United States is shown by the fact that forage, including pasture, hay, silage, and stover, forms about 55 per cent of all feed consumed by our livestock.[1] For dairy cattle, 74 per cent of the feed comes from forage; for beef cattle, 82 per cent; for sheep and goats, 94 per cent; and for horses and mules, 68 per cent. Our swine and poultry are fed mostly concentrates, forage making up only 3 per cent of the feed for swine and 5 per cent for poultry. It is shown in Chapter XXXV that the cost of producing pork can generally be reduced appreciably by making more use of first-class pasture. Also, except in intensive, large-scale poultry production, excellent pasture reduces costs.

Commonly, cattle, sheep, and horses are provided with all the forage they will consume, and then are fed in addition whatever grain and other concentrates they need to meet their requirements.

Before discussing the value and use of the various forage crops in the following chapters, it is important to consider the different methods of utilizing forage, and the factors that affect its nutritive value.

356. Abundant excellent forage increases profits.—That an abundant supply of excellent forage increases profits in livestock farming is well shown by a recent cost study on dairy farms in southern Michigan.[2] On the farms where the quality of roughage was excellent throughout the year, the annual return over feed cost per cow was $65 more than on the farms where the roughage was graded poor. Though the dairymen having excellent roughage fed 1,307 lbs. less concentrates per cow a year, their average milk yield per cow was higher than on the farms with poor roughage. An important fact was that the feed cost of producing each 100 lbs. of milk was

reduced 46 cents by providing plenty of excellent roughage.

357. Economy of pasture.—Good pasture generally supplies the most economical feed for cattle, sheep, and horses during the growing season. Even for swine, it is an important means of reducing the cost of feeding. This is in spite of the fact, pointed out later in this chapter, that the yields of nutrients are usually less when grasses and other hay crops are pastured, in comparison with their yields for hay. The difference in yield is much more than offset by the greater expense for labor, seed, and machinery in planting, tilling, harvesting, and feeding forage crops.

The economy of pasture is well shown in studies conducted by the United States Department of Agriculture in 7 dairy districts of this country.[3] In these areas pasturage furnished nearly one-third of the total nutrients consumed by the cows during the year, but the cost of the pasturage was only one-seventh of the total annual feed cost. In similar studies on 478 corn-belt beef farms, the breeding cows obtained practically all their feed from pasture for 200 days of the year. While the pastures furnished a little more than one-half the total feed for the whole year, the cost of pasture was only one-third of the annual feed bill.

On dairy farms in southern Indiana pasture furnished total digestible nutrients at 27 per cent of the cost of harvested feeds, although each acre of pasture produced only one-half as much actual feed per acre as corn or legume hay grown on the same land.[4] From cost studies on New York dairy farms it was estimated that the cost of total digestible nutrients from pasture was less than one-sixth as much as from concentrates, about one-half as much as from hay, and one-third as much as from silage.[5]

The effectiveness of pasture in reducing the cost of milk production is shown by studies on farms in various areas of New York.[6] The average total cost of producing milk on these farms during the grazing season was only 55 per cent as great per 100 lbs. as it was during the winter barn-feeding season.

When a well-adapted mixture of pasture grasses and legumes is grown on fertilized land and grazed rotationally, the yield of nutrients per acre may be nearly as great as from alfalfa hay on similar land. For example, in Maryland tests well-fertilized pasture grazed in rotation yielded an average of 2,567 lbs. of total digestible nutrients per acre during the season.[7] Alfalfa hay, grown on similar fertilized land, yielded 2.8 tons of hay per acre containing 2,926 lbs. of total digestible nutrients. Unfertilized pasture on the same sort of land, which was grazed continuously instead of rotationally, yielded only 1,552 lbs. of total digestible nutrients per acre.

358. Nutrients at different stages.—Many stockmen do not fully realize the great differences there are in nutritive value between young, immature forage crops and the same plants when they are mature or even at the usual hay stage of growth. These wide differences are shown in the data given in Appendix Tables I, II, IV, and V for different forage crops at various stages of maturity.

First of all, young plants are very much richer in protein, on the dry basis, than the same plants at later stages of growth. Thus, in the northern states young pasture grass that is growing actively usually contains 16 per cent or more of protein when dried to a hay basis. This is even more protein than there is in alfalfa hay of good quality. Young legumes, such as alfalfa and clover, are even richer than young grass in protein. On the other hand, when pasture plants become mature and weathered, the protein content may fall to a very low level.

Many farmers fail to take advantage of the fact that stock on good, actively-growing pasture receive a liberal supply of protein. For example, dairy cows on such pasture are often fed a concentrate or grain mixture containing much more protein than necessary. This does not increase their production, and it is usually decidedly uneconomical. **(1080)** Similarly, beef cattle being fattened on first-rate pasture are sometimes fed con-

siderably more protein supplement than is needed.

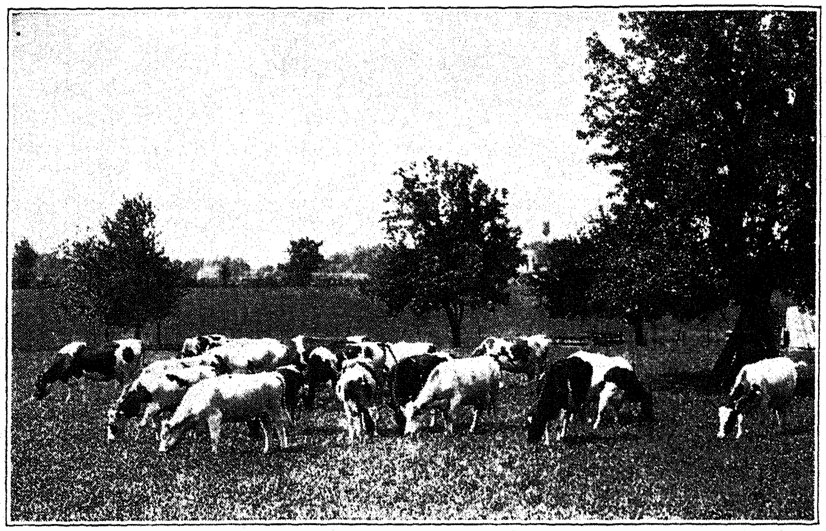
The second great difference between young plants and those that are more mature is that the young plants are soft and tender and have much less fiber and less lignin, on the dry basis, than at later stages of growth. They are therefore more digestible than hay cut at the usual time. When dried to a hay basis, mixed pasture grass and clover from fertile, closely-grazed pasture supplies 66.7 per cent total digestible nutrients, in comparison with 51.0 per cent for clover and timothy hay of good quality, cut at the usual stage of maturity. There is probably an even greater difference in net-energy value between young grass or clover and hay made from the same crop at the usual stage of growth.

When grass becomes mature, the digestibility and nutritive value are decreased still more. If it is then weathered by exposure, it will resemble a rather poor grade of straw in composition and value. The more digestible and valuable nutrients will have been largely lost by leaching or by the shattering of leaves and other finer parts.

In addition to the richness in protein and the high digestibility of young forage plants, they contain much more phosphorus, on the dry basis, than at later stages of growth and are also somewhat higher in calcium. Moreover, young forage plants are much richer in vitamins, especially in vitamin-A value.

359. Protein content at various stages of growth.—Many studies have been conducted to find the content of protein and other nutrients in various grasses and other forage crops at different stages of growth.[8] These investigations have shown that under such climatic conditions as those in the northern part of the United States, the best pasture grasses will contain, before heading out, 16 to 20 per cent of protein, on the dry basis. At pasture stages of growth, alfalfa, red clover, or Ladino clover will have, on the dry basis, 20 to 25 per cent of protein or even more.

The protein percentage in the grasses decreases greatly when they head out, largely because of the accumulation of carbohydrates. Also, after grass has headed out, there is a much smaller proportion of leaves in the plants. Grass hay,



IMMATURE, ACTIVELY-GROWING GRASS IS RICH IN PROTEIN

On excellent, actively-growing grass pasture, such as this, dairy cows do not need a concentrate mixture high in protein, for the young grass is rich in protein.

cut at the usual stages of maturity, will generally have only 6 to 9 per cent of protein, on the dry basis, and the later it is cut, the lower will be the protein content.

When grasses become mature and especially when they are weathered by exposure, the protein may fall to only 3 per cent or less, on the dry basis. Stock grazing on such grass will therefore suffer from a deficiency of protein, unless they are fed a protein supplement.

The protein percentage of legume forage crops also decreases as they advance in stage of growth, but to a much less extent than in the case of the grasses. For example, alfalfa hay cut before bloom has an average of 18.6 per cent protein, and alfalfa hay harvested after bloom still has an average of 12.9 per cent protein. (Appendix Table I.)

Under such climatic conditions as in the southern states, grasses at the pasture stage seem generally to have a much lower percentage of protein than do grasses at the same stage in a cooler climate. This is apparently the case except when heavy applications of nitrogen fertilizer are made, or on soils very high in nitrogen, such as the peat soils of the Florida Everglades district.

It will be noted in Appendix Table I, that mixed pasture grasses and legumes from fertile pasture in the southern states have an average of only 3.8 per cent protein on the fresh basis, equivalent to 15.1 per cent on the dry basis. In other districts of the United States the protein content of mixed pasture grasses and legumes from closely grazed, fertile pasture averages 22.7 per cent, on the dry basis.

LATER, THE GRASSES AND CEREALS ARE LOWER IN PROTEIN

When the grasses and cereals have headed out, the percentage of protein, on the dry basis, is much lower than at early stages of growth. Hereford cattle on rye pasture which has headed out.

360. Digestible nutrients at various stages.—Numerous experiments have shown that young pasture forage is much more digestible than the same plants at a later stage of growth. The difference is especially great when the plants become mature and will be still greater if they are weathered by exposure.

To a considerable extent the decrease in digestibility as plants become more mature is due to the increase in lignin.[9] Lignin, which is classed with the carbohydrates, although not a true carbohydrate, has a very low digestibility,

even by ruminants or horses, and other animals can digest practically none of it. (**11**) Its nutritive value is therefore much less than that of cellulose. The digestibility of older plants is also reduced because the cell walls, especially of the stems, become lignified, or encrusted with lignin. This decreases the digestibility of the nutrients which are enclosed within the cell walls.

The composition and digestible nutrients in various important pasture and hay crops at different stages of growth are shown in Appendix Table I. For example, timothy hay, cut in early bloom, has 4.2 per cent digestible protein and 51.7 per cent total digestible nutrients, on the average; that cut in full bloom, 3.2 per cent digestible protein and 51.1 per cent total digestible nutrients; and that cut at the late seed stage, only 1.9 per cent digestible protein and 41.9 per cent total digestible nutrients. Timothy hay cut at the latter stage is no higher in digestible nutrients than oat straw, although it has somewhat more digestible protein.

361. Phosphorus and calcium at various stages.—Young grasses or legumes on land well supplied with phosphorus have a good content of phosphorus, usually containing 0.25 per cent or more of it, on the dry basis. The percentage of phosphorus decreases somewhat as the plants become older, but until they are nearly mature there will generally be plenty for livestock. If the forage becomes mature and weathered, the phosphorus content falls greatly. Even where there is no phosphorus deficiency in the soil, such forage may not supply enough to meet the requirements of animals pastured on it.

Where the soil is slightly deficient in phosphorus, pasture plants may furnish enough phosphorus during active growth, but there may be a serious deficiency when the plants are mature and weathered. For example, on a New Mexico range pasture where there was a moderate deficiency of phosphorus, grasses had over 0.10 per cent of phosphorus on the dry basis during active growth.[10] When the forage became mature and weathered during the winter, it had only about one-half as much phosphorus, which was much less than stock need for health.

The percentage of calcium, on the dry basis, in grasses and other forage plants decreases somewhat as growth advances and carbohydrates are accumulated in the plants. However, the change is much less than in the content of phosphorus. Even mature and weathered grass will generally supply enough calcium for grazing animals, unless the soil is extremely deficient in the mineral.

362. Vitamin content at various stages.—One of the most important facts in livestock feeding is that all actively-growing green parts of plants have a very high vitamin-A value, because of their richness in carotene. This is shown by the analyses summarized in Appendix Table V. Such forage is also rich in most of the B-complex vitamins, in vitamin E, in ascorbic acid, and in certain unknown vitamins that are required by animals. (Chapter VII.) Good pasture therefore abundantly takes care of the vitamin needs of farm animals.

It has been pointed out previously that green plants contain little or no vitamin D. However, this is generally not of importance for stock on pasture, because their vitamin D requirements are met through the effect of the ultra-violet rays in sunlight. (**201**)

The content of vitamins, especially of carotene, decreases as plant growth advances.[11] Early-cut hay is therefore much richer in vitamins than late-cut hay, if it is equally well cured. When pasture plants mature and dry, the carotene is lost rapidly. Practically all the carotene disappears from most grasses and other pasture plants when they become mature and weathered, but if the lower parts of the stems or some of the leaves remain green, a small amount of carotene will be retained. (**196**)

363. Selective grazing.—If there is plenty of forage in a pasture, livestock tend to select the leaves and finer parts of the stems, which are more tender and more nutritious, and eat less of the coarser stemmy parts. The com-

position of the forage actually eaten may therefore differ appreciably from that of the entire plants, including all the stems.

In recent New York studies with cattle on rather mature grass pasture, they digested 60 per cent or more of the dry matter in the forage eaten.[12] However, when the entire plants were cut and fed to the cattle, only 45 per cent of the dry matter was digested. In the case of very young and palatable pasturage, there is much less selectivity in grazing.

364. Effect of rate of growth and season of year.—Grass is generally rich in protein, on the dry basis, and otherwise of high nutritive value, as long as it is kept growing actively and is prevented from heading out. Proper fertilization and good pasture management are therefore important to produce pasturage of high value throughout as much of the season as is possible.

The grass will usually be somewhat richer in protein in spring and early summer when the growth is most rapid, than later in summer. If growth is decidedly checked in midsummer by drouth, by a lack of available plant food, or by hot weather, the protein content and the digestibility will be decidedly lower than that of grass at the same stage of maturity earlier in the season. Often such pasturage will contain 12 per cent or less of protein, on the dry basis, in comparison with 16 per cent or more for rapidly-growing grass.

If the grass resumes rapid growth in the autumn after fall rains come, the protein content may be nearly as high as early in the season. In case the grass is allowed to head out and go to seed at any time, the protein content will be relatively low.

365. Differences in effects on various crops.—There are marked differences between various kinds of pasture and hay plants in the rate of changes as growth advances. Among the grasses, bromegrass retains its palatability and nutritive value over a much longer period than most grasses. The protein and carotene content fall less rapidly, and there is less increase in fiber. Sudan grass also retains a high value over a long season. At the other extreme are such grasses as orchard grass and reed canary grass, which are readily eaten by stock when young but rapidly become woody and unpalatable.

Among the grasses in the western range states, crested wheat grass starts growth earlier in the season than most of the native grasses, but does not retain its palatability and nutritive value well after the blossom stage. To make good hay, such grasses as orchard grass or crested wheat grass must therefore be cut early.

Most legume pasture and hay crops retain their palatability and nutritive value at late stages of growth somewhat better than the majority of the grasses. An exception is lespedeza sericea, which is unpalatable to stock except when very young. It soon becomes distasteful, because of a considerable accumulation in the plants of tannin, which is bitter.

366. Certain forage crops richer in nutrients when mature.—The only exceptions to the general rule that immature plants are lower in fiber and higher in total digestible nutrients, on the dry basis, than when mature, are such crops as corn, the small grains, the sorghums, and soybeans. In these crops large amounts of highly digestible nutrients are stored in the seeds as they approach maturity. The percentages of total digestible nutrients are therefore commonly higher when the seed has fully developed in such crops (considering both the seed and the stover or straw), than at an earlier stage.

367. Immature grass not a concentrate.—Occasionally, some persons become so enthusiastic about the nutritive merits of first-class pasture that they conclude it is fully the equivalent of a protein-rich concentrate. This is a considerable exaggeration.

Good pasture forage may be fully as rich in protein, on the dry basis, as wheat bran or wheat middlings, and even as rich as corn gluten feed or brewers' dried grains. In vitamin content such forage is unexcelled. However, in two

important respects the best of immature forage differs markedly from a high-grade concentrate. This is in the percentage of fiber, and consequently in the content of total digestible nutrients or net energy.

For example, corn grain has only about 2 per cent fiber, while young pasture forage will usually have 18 to 20 per cent, if dried to the same dry matter content. Because of the large difference in fiber, pasture forage furnishes considerably less total digestible nutrients, on the dry basis, than do high grade concentrates.

In content of total digestible nutrients young pasture forage of good quality is about half way between high-grade concentrates and good hay. High-grade concentrates usually have 75 per cent or more of total digestible nutrients; good hay has about 50 per cent; and first-rate pasture forage 60 to 67 per cent, when dried to a hay basis. There is an even greater difference in the net energy value of pasture forage and of high-grade concentrates.

By providing dairy cows, beef cattle, and sheep with an abundance of good pasture throughout the growing season, and with plenty of first-rate hay or hay and silage in winter, the amount of concentrates needed for good production can be considerably reduced. However, good pasture and high-quality hay cannot fully take the place of concentrates.

Dairy cows of high productive capacity need some concentrates in addition to excellent pasture and other high-quality roughage, or their milk yield will be much reduced. (**1023**) This is well shown by Montana tests in which cows that had been fed a liberal amount of concentrates the previous year, were then fed for a year on only roughage of the very best quality.[13] During the grazing season this was pasture on irrigated land, and in winter either hay or silage made from immature pasture forage. On roughage alone the cows yielded only 63 per cent as much milk, on the mature-equivalent basis, as during the previous year when they had been fed concentrates in addition.

Similarly, concentrates are needed in addition to good pasture to produce a good degree of fatness, or finish, on young beef cattle. In the case of pigs and poultry, the difference in the effects of young forage plants and of concentrates is still greater. This is because their digestive tracts do not enable them to eat a great amount of roughage. Even with the best of pasture as the only feed, pigs will not make normal growth, to say nothing about fattening. Though good pasture is important in poultry production, it cannot replace much of the concentrates.

368. Mature, weathered forage usually of low value.—In the semi-arid range districts, stock usually get most of their feed during the winter or during the dry season by grazing on forage which has matured and dried. As we have seen, mature grass is always low in protein and phosphorus and may have practically no carotene. If it is weathered by exposure to rains, the value will be lessened still further by leaching.

Where there is little or no rainfall after the grass matures, there is less loss through weathering, but still the mature grass will have a much lower value than before it matures. For this reason, cattle and sheep on range pasture make most of their gains in weight during the period when the forage is growing actively.

Weathered, mature forage resembles straw in composition and feeding value. It is very low in protein and phosphorus, it has practically no carotene, and it is lacking in palatability and is low in digestibility. When badly weathered, the forage may not even furnish enough nutrients for body maintenance. If stock receive no other feed, they may suffer severely from nutritive deficiencies. For example, it was found in California studies that because of the lack of carotene, cattle or sheep which had only such weathered range forage for long periods were often unable to produce normal offspring. (**192**)

Some forage plants lose much less nutrients by weathering than do others. For example, the wire grasses and sedges of the West often furnish much more nutritious winter feed than other grasses. Also, bur clover makes good feed even when mature, and winter fat (often called white sage) and some of the true sages have a good feeding value in winter. In general, the nutritive value of the grasses falls more with maturity and weathering than the value of the browse which stock get from the leaves and small twigs of shrubs.

369. Effect of grazing or frequent cutting on yield.—When grasses or legumes are cut at frequent intervals throughout the season, as on a well-kept lawn, the total yield of dry matter is usually much less than when they are allowed to grow to the usual hay stage.[14] This is because there is then a smaller leaf surface exposed to the sunlight. Therefore, the production of carbohydrates through the action of sunlight on the chlorophyll of the leaves is decreased. The same result is produced by close grazing of the crop.

The effect of frequent cutting or of close grazing will depend on the kind of plants and also on other factors. The yield of tall-growing plants, such as alfalfa, red clover, alsike clover, orchard grass, and the ordinary kinds of timothy, is reduced much more than that of low-growing spreading pasture plants, such as Kentucky bluegrass, Bermuda grass and white clover. Too-frequent cutting or too-close grazing of the taller plants may also seriously lessen their vigor, because of depletion of reserve food in the roots. This not only reduces the yield but may cause the plants to die out.

Differing from the yield of dry matter, the total yield of protein during the season may be greater when the crop is cut frequently or grazed than when it is cut for hay. Also, since very immature plants are lower in fiber and more digestible than at the hay stage, the yield of total digestible nutrients is not reduced so much as the dry matter.

In general, pasture mixtures of grasses and legumes which are cut every 2 to 3 weeks will yield only 50 to 70 per cent as much dry matter and 60 to 75 per cent as much total digestible nutrients during the season, as when they are harvested at the usual hay stages. In Pennsylvania tests pasture mixtures cut every month yielded only 66 per cent as much dry matter over a 5-year period as when 2 cuttings a season were made for hay.[15] Cutting the pasture mixture every week or continuous close grazing will reduce the yield even more.

Because continuous close grazing tends to reduce the yield of most pastures, the production of forage is usually increased somewhat when a system of rotation or alternate grazing is used instead. (376)

370. Effect of soil and fertilizers on composition.—Not only is the yield of a forage crop dependent on the amount of mineral nutrients in the soil, but also its composition may be greatly affected. Many experiments have been conducted to determine the effect of soil fertility and fertilizer applications on the composition of pasture, hay, and other forages.[16] Only a very brief summary of the more important findings can be presented here.

It is fortunate that the soil treatments which give the highest crop yields also generally produce forage of high nutritive value. Such forage will usually have a good content of protein and minerals, and it is apt to be richer in vitamins than forage that has made poor growth because of a lack of soil fertility.

Properly fertilized pasture plants continue growth over a longer period than those on infertile soil, and thus provide good feed for a longer time. Another important advantage is that pasturage on well-fertilized land is more palatable to stock than that grown on poor land. (98) This may largely be because the plants are more succulent.

Except where forage is deficient in phosphorus or in one of the trace minerals, the chief benefit from applying fertilizer to pastures or meadows is usually from an increase in yield, or from

an increase in the proportion of legumes. A larger proportion of legumes will, of course, decidedly increase the richness of the mixed forage in protein, calcium, and vitamins. Also, the nitrogen supplied by the legumes will tend to increase the protein content of the grasses in the mixture. (**449**)

Commonly, the yield of forage on phosphorus-deficient soil will be increased by phosphate fertilization much more than enough to repay the expense. In addition, liberal phosphorus fertilization will usually correct any phosphorus deficiency in the forage. However, a moderate application of phosphate to such a soil may at first only increase the yield, without increasing the percentage of phosphorus in the crop.

On phosphorus-deficient range pastures in the drier regions, the forage production per acre may be so low that it may not be at all practical to apply phosphate fertilizer to the soil. In such cases the phosphorus deficiency in the forage can readily be corrected by feeding bone meal or some other safe phosphorus supplement to the stock, as advised in Chapter VI. (**158–167**) Any deficiency of a trace mineral, such as cobalt, copper, or iron, can likewise be corrected by adding the trace mineral to the salt. (**172–173, 175**)

Where legumes do not thrive because of a lack of lime, phosphorus, or potash, adequate fertilization will commonly improve the nutritive value of pasturage and hay greatly. This is because it will increase the proportion of legumes in the forage.

Grass grown in partial shade, as in open woods, not only produces much less forage than that fully exposed to sunlight, but also is less palatable. This is probably because it has less sugars and starch.

371. Phosphorus and calcium content.—It has been emphasized in Chapter VI that grass or other forage grown on soil very deficient in phosphorus may be so low in this mineral that stock grazed on it suffer disastrously, unless fed a phosphorus supplement. (**150**) Pasture grass on phosphorus-deficient soil may contain less than 0.10 per cent phosphorus on the dry basis, in comparison with 0.20 to 0.40 per cent or more for grass from fertile pastures. In Texas studies it was concluded that pasture forage having less than 0.15 per cent phosphorus on the dry basis did not supply enough to meet safely the requirement of beef cattle grazed on the pasture without other feed.[17]

Legume forage is also much lower in phosphorus content than normal when grown on phosphorus-deficient soil, but the content does not usually drop to quite such a low level as in the case of the grasses. However, most legumes are exceedingly sensitive to a lack of this mineral nutrient and do not thrive or yield well unless there is an ample supply of phosphorus.

The percentage of calcium in non-legume forage crops is considerably reduced when the crops are grown on soil deficient in calcium. However, the calcium content is not often so low that livestock suffer from a lack of calcium. (**149**) While the percentage of calcium in legume forages depends to some extent on the calcium content of the soil, they are always relatively high in the mineral. When the soil is too deficient in calcium, the legume crop will not thrive, but the small amount of forage produced will be fairly high in calcium.

372. Protein content.—The yield of non-legume forage crops often depends largely on the amount of nitrogen in the soil. However, the percentage of protein in such crops is not affected by the supply of soil nitrogen to any such extent as a deficiency of soil phosphorus lowers the content of this mineral.

In the case of the grasses, the protein percentage at immature stages of growth is usually increased materially by nitrogenous fertilization, unless the soil is already well supplied with nitrogen. This increase may be sufficient to add appreciably to the feeding value of grass pasture or of grass hay cut very early. Also, nitrogen fertilization increases the palatability of the grasses.

The application of nitrogen fertilizer to grass early in the spring may not

increase the protein content appreciably at the usual hay stage, though increasing the yield considerably. By making a second application of nitrogen when timothy was heading out, the protein content of timothy hay was increased over 1 per cent in New Jersey tests.[18] By very heavy and repeated applications of nitrogen to Coastal Bermuda grass in experiments in southern Georgia, an average of 7.8 tons of hay per acre was secured, containing the high content of 12.7 per cent protein.[19]

Proper inoculation and also liming, when necessary, not only increase the yield of alfalfa and other legume forages, but in addition make them richer in protein. On the other hand, if such crops are well inoculated with the proper bacteria, nitrogenous fertilization will not produce much increase in the percentage of protein in the plants.

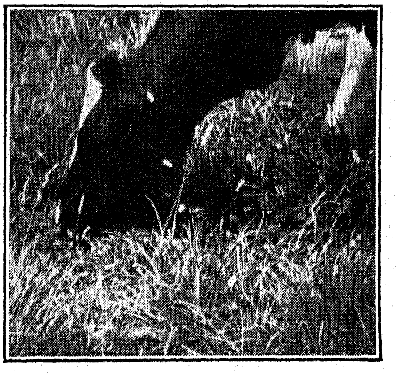
II. The Improvement and Utilization of Pasture

373. Importance of pasture improvement.—In spite of the great importance of pastures for livestock, pasture improvement received relatively scant attention in this country until recent years. All too commonly, farmers made little effort to increase the productivity of their pastures. They failed to treat pasture as a valuable crop. If the soil was fertile and the summer rains were timely, their stock thrived during the grazing season. On the other hand, if lack of fertility or drouth caused a serious shortage of feed in midsummer, the returns were much decreased.

Now, however, there is wide-spread interest in pasture improvement, and progressive farmers fully appreciate its importance. This change has come about largely through the numerous pasture experiments and demonstrations carried on by the state experiment stations and agricultural colleges, by the United States Department of Agriculture, especially through the Soil Conservation Service, and by other agencies. In addition, much excellent work on pasture improvement has been done abroad.

These studies show convincingly that in most localities a great increase can readily be made in the yield of pastures, and that wise expenditures for this purpose are usually highly profitable. In nearly all regions, pasture improvement will greatly reduce the cost of livestock production.

It is outside the scope of this volume to discuss in detail the fertilization and management of pastures under the various conditions throughout the country, or to review the results that have been secured in the numerous pasture investigations.[20] All that can be done is to summarize briefly certain of the most important findings. For further information the reader is referred to the publications of his state experiment station or agricultural college, or to those of the United States Department of Agriculture.



Cows Need Abundant Pasture

A cow has only a 3 to 4 inch "lawn mower" to harvest forage. Abundant pasture is needed, so she can get her fill without undue exertion. (From New York State College of Agriculture.)

Wherever a suitable legume will thrive in a pasture mixture, a much higher yield of forage is usually secured from a legume-grass mixture than from grasses alone. Such forage will have a considerably greater nutritive value, because of its higher content of protein, calcium, and vitamins. Also, a well-adapted legume-grass pasture will generally provide good feed over a much longer season than grass alone. Among

the legumes that are widely used in pasture mixtures in various parts of our country are alfalfa, Ladino clover, white clover, birdsfoot trefoil, and lespedeza.

The best mixtures to use for pasture on any particular farm is a local problem, the choice depending on climate, soil, and level of fertility. Therefore, anyone in doubt as to what mixture to use should consult his county agent or agricultural college, describing his local conditions. In a pasture mixture all the species of plants should be about equal in palatability. Otherwise the stock may not eat the less palatable plants.

Unless one is sure that the pasture will be well managed and tall growth will be clipped when necessary, it is a mistake to include in a mixture for a large pasture such a grass as orchard grass or tall fescue, which is low in palatability except when very young.

374. Proper grazing essential for high pasture yields.—Proper grazing management is essential for good results from any pasture. The chief objects are: (1) To keep the pasture plants growing actively over as long a period as possible, so they will provide palatable feed of high value; and (2) to encourage the growth of desirable grasses and legumes, while weeds, brush, and inferior grasses are crowded out. In general, the protein content of pasturage depends much more on proper management than on fertilization.

In all humid districts the pasture should be so managed that the grasses do not head out and go to seed. If the plants mature, the forage becomes unpalatable and of low nutritive value. Moreover, the new growth is diminished, and what there is may be wasted, because stock will refuse to eat the mature grass along with it. In addition, if the grasses grow so high as to shade a low-growing legume, such as white clover, they will drive it out. Weeds, brush, and coarse grasses are, moreover, apt to gain a foothold when the pasture is grazed insufficiently. A good rule is to graze the pasturage all down closely at least once a year.

Overgrazing throughout the season is one of the most common faults in pasture management. It not only reduces the yield, but it also weakens and drives out the most desirable pasture plants, because they are eaten down so closely that there is no opportunity for them to store reserve nutrients in their roots. Injury is especially apt to result if heavy grazing is begun before sufficient growth is made in the spring, and if the fall growth is grazed so closely that no cover is left for winter protection. In addition to these bad effects of overgrazing, it greatly increases soil erosion.

Such low-growing plants as Kentucky bluegrass and wild white clover will stand continuous close grazing much better than taller-growing plants. Alfalfa, Ladino clover, and bromegrass are all apt to be injured severely by constant close grazing and give the best results when grazed by the rotation method. (376)

In a pasture mixture of a tall grass with low-growing white clover or even Ladino clover, if the grass grows up too tall it will shade the clover and tend to kill it out. Such a pasture should therefore be grazed heavily during the flush of spring growth, so as to keep the grass down. If the forage gets ahead of the stock, the field should be cut for silage or hay.

In range areas stock commonly secure all or most of their feed in winter or in the dry season from standing mature grass and other forage that has been saved for this purpose. The nutritive value of such feed is apt to be so low that mineral or protein supplements are needed in addition.

Even in humid districts occasionally a field is not pastured the latter part of the season, but instead the forage is allowed to grow up and mature so as to supply feed late in the fall or in the winter. The advisability of such a practice will depend chiefly on the usual weather at that time of the year. At best, such forage is much less nutritious than immature forage or than good hay or silage.

375. Other points in pasture management.—Even when a pasture is well

managed, stock are apt to graze it unevenly. Some of the grass will head out and then may not be eaten during the rest of the season. If the land is not too rough or stony, it is wise to mow all such spots at least once a year at the usual haymaking time or before, to get rid of the old grass and to encourage new growth. It is especially important to cut all weeds and brush. If there is a uniform stand of good pasture plants in the pasture, with but few weeds, there may not be much advantage in mowing it when it is rather heavily grazed.

Stock will not graze the rank rings of grass around piles of droppings in the pasture, unless forced to it by hunger. Therefore in heavily-stocked cattle or horse pastures, there is considerable wastage of feed unless the droppings are spread at least once a year with a harrow.

A field will be grazed more uniformly if more than one kind of stock is pastured on it, and the return from the pasture may be thus increased.[21] Rotating two or more species of stock not only helps to control grazing, but it also aids in reducing the trouble from internal parasites.

For efficient use of the pasture, it is important to provide a good supply of water and also shade. Since stock on good pasture spend much of their time in the shade, if it is available, fertility is conserved when shade trees are located at the top of a slope, instead of at the bottom of the slope or on the banks of a stream.

The stock should be turned on a pasture in the spring just as soon as the plants have made sufficient growth and the soil is firm enough to stand trampling. If grazing is delayed longer, it may be impossible, during the period of rapid growth which follows, to prevent much of the grass from becoming too mature.

Grazing farm woodlots in the northern states is undesirable, for the stock secure but little feed and the reproduction of desirable trees is largely prevented. In a 5-year Wisconsin test, woods pasture produced only 276 lbs. of dry pasture forage per acre, in comparison with 1,453 lbs. for untreated open pasture and 3,210 lbs. for renovated pasture.[22]

North Carolina experiments indicate that careful grazing in the pine forests of the southeastern states may not do much damage to the forest growth, and it reduces the danger from damage by fire.[23]

Sometimes grass pastures are burned early in spring to remove dead vegetation or to kill undesirable shrubs.[24] While such burning may increase the spring growth of grass, annual burning is apt to be decidedly injurious over a term of years. This is because it destroys much organic matter and increases danger of erosion. Burning pastures is therefore advisable only under special circumstances and when recommended by agronomists familiar with local conditions.

376. Rotation or alternate grazing. —Especially for well-fertilized, high-yielding pastures, the method of rotation or alternate grazing is often used, instead of keeping the stock continuously on a single field throughout the season. Even on permanent pasture, rotation grazing tends to increase the yield of forage slightly. It is more advantageous with such pasture crops as alfalfa, Ladino clover, and bromegrass, which are injured by continuous close grazing. Such a combination as alfalfa or Ladino clover with bromegrass, timothy, or orchard grass, grazed rotationally or at least not overgrazed, will generally furnish much more good forage in midsummer than any permanent pasture.

In rotation grazing, there are 2 or more separate fields which are pastured in succession. After each area is grazed down, the animals are removed, and the forage is allowed to grow up to a height of 4 to 6 inches, before it is grazed again. Most of the feed is therefore eaten when it is rich in protein and digestible nutrients, and before it becomes less palatable. If the rainfall is abundant and the grass grows so fast the stock cannot graze it all, one of the areas should be cut early for silage or for hay, to prevent the bad effects of under-

grazing. The second growth of this area will then provide pasture during the midsummer season, when there is usually a shortage of good pasture.

Additional fencing is required for rotation grazing, and each plot must be accessible to a water supply. This can often be provided best by having the plots open into a common lane, where water is available.

Numerous experiments have been conducted in various parts of this country to compare rotation grazing with well-managed continuous grazing for dairy cows,[25] dairy heifers,[26] beef cattle,[27] and sheep.[28] These studies show that rotation grazing is very desirable for those pasture crops that do not stand continuous grazing well. Such pastures are alfalfa, Ladino clover, and mixtures of these legumes with a suitable grass. In most experiments rotation grazing of a permanent pasture has not increased the yield of forage enough to warrant much additional expense. In such trials the increase from rotation grazing has not exceeded 10 per cent, and in some experiments there has been little or no difference in yield.

High-producing dairy cows are benefited by rotation grazing more than are dairy heifers or beef cattle. This is because a high-yielding cow must have an abundance of feed throughout the season, or her milk flow will be seriously reduced. If her milk yield has once fallen badly, it is difficult to bring it back later by liberal feeding. On the other hand, while short pasture will reduce the gains of growing or fattening cattle, they will again make good gains later in the season if the forage becomes plentiful.

Rotation grazing is important for sheep, as it aids in preventing trouble from internal parasites. It is of similar advantage for horses or cattle in any area where infection with internal parasites is serious. In swine production fresh pasture, on which no swine have grazed that season, is exceedingly important for the young pigs at weaning time.

377. Strip grazing or rationed grazing.—Very recently there has been considerable interest in this country in "strip" or "rationed" grazing. In this method, which is often used in New Zealand for dairy cows, a fresh strip of pasturage is provided each day for the stock by means of electric fences. The width of each strip is adjusted so that it will furnish enough feed for the day. By this method there is less injury of the plants by trampling, but considerably more labor is required than in continuous or rotation grazing.

In a California experiment with dairy cows there was no appreciable difference in the results from strip grazing and from well-managed rotation grazing of irrigated Ladino clover-orchard grass pasture.[29] In a Minnesota test with heifers, the yield of forage was much greater with strip grazing than with continuous grazing, but the continuously grazed pasture was permitted to grow up without being clipped.[30]

In a California experiment with beef steers, 39 per cent more beef per acre was produced on alfalfa or alfalfa-grass pasture when strip grazed than when rotationally grazed.[31] The beef production per acre was still higher when the forage was cut and fed as green soilage. (387)

Comparisons over several seasons are needed to determine just how much increase in production can generally be expected from strip grazing, in comparison with well-managed rotation or continuous grazing.

378. Methods of pasture improvement.—The methods to be used in improving a run-down pasture should depend entirely on the conditions in that particular pasture. Proper grazing management is always necessary to get the best yield from pasture, but this alone will do little to improve a poor pasture.

If a run-down permanent pasture still has a fairly good distribution of desirable pasture plants, fertilization alone may be all that is needed to increase decidedly the yield of forage and to improve its nutritive value. Usually phosphorus fertilization is required on such a pasture, and lime or potash may also be needed. Adequate fertilization will greatly increase the stand and vigor of

desirable grasses and also on suitable soil will tend to bring back white clover or other adapted native legumes. Unless such fertilization will bring a considerable proportion of legumes into the pasture, nitrogen fertilization also will generally be needed.

Many experiments during recent years have shown that certain newer pasture combinations greatly surpass in yield and feeding value such permanent pastures as Kentucky bluegrass in the North or Bermuda grass in the South. Desirable combinations are alfalfa with bromegrass or timothy, Ladino clover with grass, and lespedeza and grass. More complex mixtures are often desirable, because the soil and drainage conditions may differ considerably in various parts of a field. Some of the plants in the mixture may thrive best in certain areas, while in other spots they may not do well, but will be replaced by plants that are suited to the conditions there.

If a run-down pasture is tillable, the best results are usually secured when the field is plowed, fertilized properly, and reseeded with an adapted high-yielding pasture mixture. Several experiments have proved that such pastures greatly excel well-fertilized permanent grass pastures. For example, in an Indiana test 2 acres of good bluegrass pasture were needed per dairy cow, while only 1 acre per cow of alfalfa-brome pasture provided a better supply of forage.[32] In addition, the growth of forage was sometimes so rapid the first part of the season that the excess was used for hay-crop silage. The superior nutritive value of the alfalfa-brome pasture is shown by the fact that the daily yield of milk per cow was 10 per cent higher than for the cows on the bluegrass pasture.

In Wisconsin tests the average yield of dry matter per acre over a 6-year period was 6,834 lbs. from alfalfa-brome pasture for dairy cattle.[33] Bluegrass pasture with complete fertilization, including nitrogen, yielded only 3,871 lbs. of dry matter a year over a 9-year period, and bluegrass without nitrogen fertilization but 2,361 lbs.

Similar improvement can be made in pasture for other classes of stock by plowing, fertilizing, and reseeding to a good pasture mixture. In the southern states the results are especially striking, because pasture can be provided during most of the year by a suitable combination of legumes and grasses. Thus, on light soil in Georgia the average yearly gain of beef steers on unimproved carpet grass pasture was only 76 lbs. per acre over a 10-year period.[34] On pasture which was reseeded to a mixture of Dallis grass, carpet grass, lespedeza, and white clover and which received a complete fertilizer, the average yearly gain per acre was 321 lbs. for the same period.

379. Renovating permanent pasture.—Old hillside pastures where there is danger of serious erosion if the land is plowed, and also pastures that are so stony or rough that plowing is difficult, can be successfully renovated without plowing. This is done by cutting up the sod thoroughly very early in the spring with a disk, spring tooth harrow, or cultivator, smoothing with a harrow, fertilizing adequately, reseeding with a suitable mixture of legumes and grass, and then covering the seed with a harrow or cultipacker. Stock must be kept off the renovated area until the new plants become well established.

In Wisconsin tests the annual yield of dry matter per acre on renovated pastures with moderate slope was double the yield on unrenovated pastures.[35] On steeper slopes the yield was increased still more.

380. Pasture fertilization.—Pasture fertilization is of two general types. The first is fertilization with phosphate or phosphate and lime, and with potash in addition, if needed. In this type of fertilization legumes are relied upon as the source of additional nitrogen. In the second type of fertilization nitrogen fertilizer is also applied.

The choice between the two methods should depend on the local conditions. Where a pasture mixture can readily be established and maintained which contains a considerable propor-

tion of a high-yielding legume, such as alfalfa or Ladino clover, there is no need of nitrogen fertilizer. Indeed, such a legume-grass combination will provide a much more uniform supply of feed throughout the summer than can be obtained from grass pasture, even with liberal fertilization. This is because these legumes make much more growth in midsummer than do most grasses, especially Kentucky bluegrass.

The forage from such a legume-grass pasture is also even richer in protein, minerals, and vitamins than the forage on a well-fertilized grass pasture. In addition, the cost of securing additional forage from pasture is much less when legumes are used to furnish nitrogen than when nitrogen fertilizer is used on a grass pasture, like Kentucky bluegrass.

This is shown in Wisconsin experiments in which bluegrass pasture with complete fertilization, including nitrogen, was compared with pasture in which a combination of alfalfa and grass was maintained by suitable renovation.[36] Both of these pastures were compared over a 7-year period with a bluegrass pasture which was fertilized with lime, phosphate, and potash, but with no nitrogen fertilizers. In comparison with this latter pasture, the alfalfa-grass mixture furnished additional digestible nutrients at only about one-half the cost of the additional forage secured by the use of the nitrogen fertilizer on bluegrass pasture.

By liberal use of a complete fertilizer, including nitrogen, on grass pasture, high yields of forage can be secured. Unfortunately, however, most of the additional growth from nitrogen fertilization comes in the spring and fall, when pasture is usually plentiful, and not during the period of midsummer shortage. This is because such grasses as Kentucky bluegrass make but little growth in hot, dry weather, even when liberally fertilized. On the other hand, plants such as alfalfa, bromegrass, or orchard grass, which are deeper-rooted and more drouth resistant, will continue to make considerable growth. Though Ladino clover is not very deep rooted, it makes much more growth in midsummer than bluegrass, unless drouth is severe.

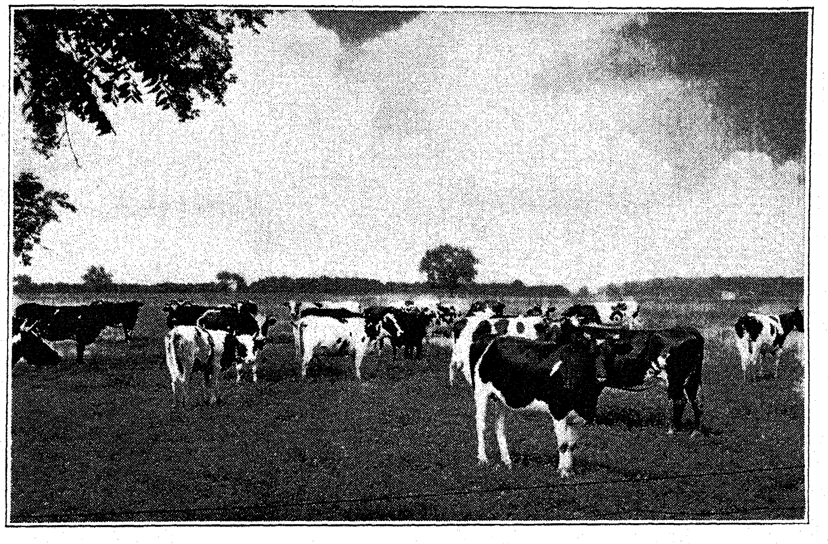
Nitrogen fertilization very early in the spring will stimulate the growth of grass so that the pasture will often be ready for grazing 10 days to 2 weeks earlier. By such fertilization of a suitable pasture field, the barn-feeding period for a dairy herd can generally be reduced appreciably.

381. Intensive pasture fertilization.—An intensive method of pasture fertilization, combined with rotation grazing, is sometimes used on dairy farms where the pasture area is very limited, as is often the case near large cities. Complete fertilizers are applied in liberal amounts, including a nitrogen fertilizer in early spring. Frequently nitrogen fertilizer is also used during the growing season to keep the forage growing rapidly over as long a period as is possible. The liberal fertilization with nitrogen stimulates the growth of grasses so much that they tend to crowd out legumes from the pasture.

In this system the pasture is divided into 4 to 8 paddocks, about equal in size, and often the herd is divided into 2 or more groups. The first group, consisting of the cows in milk, are pastured first for a few days on each plot in succession, thus getting the most liberal supply of forage. Then the dry cows and the heifers are turned into the plot to complete the grazing. Sometimes the cows in milk are divided into 2 groups, and the high producers grazed first on each plot.

In this system it is important to distribute the droppings by harrowing at least once a year. Also, a plot should be mowed whenever necessary to prevent the grass going to seed. Even under this system, it is difficult to provide ample forage on the pasture area itself during midsummer. Therefore, additional grazing should be furnished at that time, if necessary, by a field that has been cut early for hay, by Sudan grass pasture, or otherwise. This system is often called the Hohenheim system, from the Hohenheim Agricultural College in Germany, where it was first developed.

Experiments with this system in this country have shown that the yield of nutrients can often be increased 2 to 4 times over that on unfertilized pastures grazed by ordinary methods.[37] The cost of such a system of fertilization and management is considerable, but where the pasture area is limited, the method may yield good net returns, on account of the saving of other feed. It is doubtful whether even under these conditions it is as economical as the use of such legume-grass pasture mixtures as alfalfa-bromegrass or Ladino clover and grass, where such mixtures do well.



ABUNDANT MIDSUMMER PASTURE ON EARLY-CUT HAY FIELD

An excellent way to supplement short midsummer pasture is to use for pasture at this time the second crop on a mixed grass-and-legume hay field which has been cut early.

382. Providing good pasturage over a long season.—In order to secure the greatest net returns from livestock, it is essential that an abundant supply of good pasturage be provided over just as long a season as is possible. It has been pointed out in this chapter that such legume-grass combinations as alfalfa with bromegrass or Ladino clover with grass excel in providing high-quality forage over a long period. In particular, these combinations far surpass such permanent pasture as Kentucky bluegrass in furnishing feed in midsummer. However, even with these excellent combinations, there may often be a shortage of pasturage during a midsummer drouth.

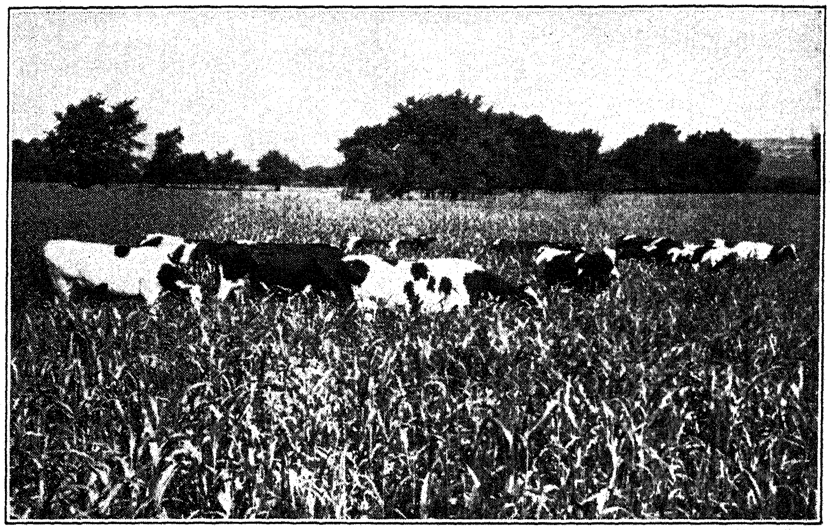
Especially for dairy cows, it is very important that additional roughage be supplied whenever there is a shortage on their regular pasture. An excellent way to supplement short midsummer pasture is to use for pasture at this time the second crop on a mixed grass-and-legume hay field that has been cut early.

Another method is to grow an annual crop like Sudan grass for pasture at this time. Sudan grass is especially adapted for midsummer pasture, for it stands drouth well and thrives in hot weather. If there is no drouth in midsummer and the Sudan grass is not needed for pasture, it can be made into hay or silage.

If pasture becomes short and no supplementary pasturage is available, then dairy cows should be fed silage, hay, or a green soiling crop to supplement what forage is available. This is generally much more economical than to keep up milk production by considerably increasing the amount of concentrates

fed the cows. It is shown later in this chapter that in this country silage generally furnishes cheaper feed than do soiling crops for supplementing short pasture. (386)

In the southern states it is important to utilize the mild winter climate fully by providing, over as long a period as possible, fall and winter pasture on legume-grass mixtures or on winter grain. Even in the more northern states the pasture season can be lengthened somewhat in spring and fall by pasturing winter grain. As has been mentioned previously in this chapter, early spring application of nitrogen fertilizer on grass pasture will often make it possible to turn stock on pasture 10 days to 2 weeks earlier.



SUDAN GRASS PROVIDES EXCELLENT MIDSUMMER PASTURE

Sudan grass furnishes excellent pasturage in midsummer when the forage on permanent pastures is apt to be scanty. (From New York State College of Agriculture, Cornell University.)

383. Nutritive value of fertilized and unfertilized forage.—Several experiments have been conducted to compare the production by livestock on fertilized and unfertilized pasture, and in other tests hay from a fertilized field has been compared with that from an unfertilized field. These experiments show clearly that when a soil deficiency causes the forage to be lacking in phosphorus or any other nutritive essential and the lack is not corrected by feeding a mineral or other supplement, proper fertilization to overcome the deficiency will be of great benefit.

For example, in recent California experiments in a phosphorus-deficient area of the Imperial Valley, steers fattened on alfalfa hay alone from unfertilized land made decidedly smaller gains and required more hay per 100 lbs. gain than did steers fed hay from phosphated land.[38] Similar results were secured in North Carolina trials with lambs fed soybean hay from phosphated and unphosphated land.[39] In an area of Oregon where the soil is extremely low in sulfur, sulfur fertilization not only greatly increased the yield of alfalfa, which has a high requirement for this mineral, but it also considerably improved the value of alfalfa hay for fattening lambs.[40]

Even when a suitable mineral supplement is supplied the animals, the forage from a well-fertilized pasture will usually produce much better results than that from an infertile field. This is chiefly because the rate of growth will be more

rapid and more continuous. There will therefore be a better supply of feed throughout the season. The fertilized forage will also be more palatable, and the animals will hence eat a greater amount per day. Another advantage is that the proportion of legumes in a pasture mixture is usually increased by suitable fertilization. This decidedly increases the value of the forage, as has been pointed out previously.

The extent of the difference between the production of stock on unfertilized pasture or hay and on pasture or hay from fertilized land will depend primarily on whether or not any nutritive deficiency results from feeding the unfertilized forage. For example, when the concentrate mixture fed dairy cows supplies plenty of phosphorus, a higher phosphorus content in hay produced by phosphorus fertilization may not make the hay more valuable per ton. However, the fertilization may be decidedly profitable because of the increased yield secured.

Though the forage from unfertilized land may be very scanty in amount, the nutritive value per pound may be as great as that of the abundant forage from a well fertilized field. This is shown by experiments with dairy cows at the Michigan, Nevada, and Virginia Stations.[41]

The most extensive of these experiments was that by the Michigan Station. In this investigation part of a rundown farm was limed and heavily fertilized with a complete fertilizer, including trace minerals. The other part received no lime and no fertilizer, except that some nitrogen fertilizer was necessary to grow enough feed for the cows. One group of cows was fed entirely on feed from the unfertilized area, and another group on that from the well fertilized land.

No legume forage was grown on either part, because alfalfa or clover would not grow on the unfertilized runout soil. The cows in each group were fed a balanced ration made up of timothy and bromegrass hay and a concentrate mixture of ground grain and soybeans, all raised on the respective area. Of course, a far larger acreage of land was needed on the unfertilized part of the farm to produce the feed for each cow.

The results were surprising. During 5 years no difference in the feeding value of the two rations could be detected. The cows fed the ration from the unfertilized land were just as healthy and produced as much milk as the others, and there was no difference in the nutritive value of the milk.

384. Supplemental irrigation of pastures.—With the development of readily movable irrigation systems, consisting of sprinklers and light-weight aluminum pipe, some farmers in the humid regions of the United States are now using supplemental irrigation to keep pastures growing during drouths. This is usually done on improved, well fertilized pastures seeded to a mixture that has high productive capacity.

The increase in yield obtained by such irrigation depends, of course, on the amount and distribution of rainfall in the particular season. In several tests by experiment stations, supplemental irrigation in humid regions has usually increased the yield of pasturage by 30 to 40 per cent or more, except when the rainfall during the season was plentiful and well distributed.[42] The economy of this method of increasing pasture yield depends largely on the cost of securing a supply of water that will be adequate when needed.

In the western irrigated districts high yields of pasture forage are obtained on fertile soil with proper management. For example, in western Montana the average carrying capacity on a good irrigated pasture mixture over a 10-year period was 2.2 dairy cows per acre during the season.[43]

385. Range management and improvement.—While it is generally best in humid districts to graze pastures sufficiently close so that the grasses do not go to seed, the conditions are entirely different on the western ranges. On account of the limited rainfall, care must be taken there not to overgraze the land. Otherwise, the desirable forage plants

will be killed and only those left which are relatively unpalatable and of low value. Also, the land will then be subject to much more injury by erosion.

To produce the most feed, the grasses must have a chance to form seed at least every 3 or 4 years, and the following spring the young seedlings should be given a chance to grow. No range should be grazed in the spring until the grass has made sufficient growth and the soil is reasonably dry. Poisoning of stock often results from forcing the animals to graze the scanty growth too early, for some of the poisonous plants start growth earlier than the grasses or other good forage and are therefore eaten, when they would otherwise be left untouched.

The range should not be grazed so heavily that the forage is injured badly by trampling or unduly close cropping. Otherwise, not only will the grasses and other herbaceous plants be destroyed, but also the shrubby browse will be injured, which forms a large part of the feed on some of the mountain ranges. Watering places should be developed close enough together to avoid overgrazing near the water supplies. Salting the stock at well-selected places will aid in relieving areas that are being injured by too close grazing. In normal years, when the stock come off a range, it should be in good condition and with some feed left.

Through improper management and unrestricted grazing, the carrying capacity of many western ranges was seriously reduced. During recent years much valuable information has been secured about the best methods of range restoration and improvement and of reseeding abandoned crop land in experiments by the state experiment stations and the United States Department of Agriculture.[44]

Where a range has been so badly injured that few desirable plants are left, reseeding may be advisable, if the rainfall is usually sufficient to secure success. More commonly, grazing on part of the area is deferred until after the grasses have matured seed. The following year, another area is similarly treated. This method of deferred and rotation grazing usually increases the carrying capacity of the range considerably, unless the pasturage is already better than the average. In some experiments the carrying capacity of range land has been considerably increased by a method of increasing the absorption of rain and reducing run-off, such as pitting, chiseling, or furrowing the land. On some ranges, it may be possible to spread the water at times of high water in a stream, by means of small dams.

The great improvement that results from controlled grazing and proper management has been well demonstrated in the National Forests, where the grazing is under very definite regulations.

III. Soiling Crops

386. Soiling crops.—*Soiling crops* are green forage crops that are cut and fed in fresh condition to stock. Soiling crops are often called "soilage." Years ago the growing of a succession of soiling crops was sometimes advocated in this country to furnish green feed throughout the growing season, especially for dairy cows.

It has been pointed out previously in this chapter that a considerably larger yield of nutrients is generally secured when a crop is allowed to grow to the hay stage than when it is kept grazed during the season. For this reason, and also because none of the forage is wasted by the trampling of stock, an acre of land will usually furnish much more feed when used for soiling crops than for pasture. In addition, less fencing is needed than when the feed is furnished by pasture.

These advantages of soiling crops were, however, more than offset by the high cost of growing special soiling crops and harvesting the forage each day by the means then available. Therefore this method was used here but little.

Experiments by the Iowa, Nebraska, and Wisconsin Stations showed definitely that the production of dairy cows was maintained just as well on silage plus limited pasture and a suitable supply of

concentrates, as when soiling crops were fed in place of the silage.[45] Also, the cows liked corn or sorghum silage as well or even better than a succession of different soiling crops.

In the Iowa trials it required 180 lbs. of soiling crops to equal 100 lbs. of corn silage in feeding value, because the soiling crops contained much smaller percentages of dry matter and digestible nutrients. In the Nebraska trials a much larger area was needed per cow to provide the feed when soiling crops were used, than when corn silage and alfalfa hay were fed.

Because of the expense involved in using special soiling crops, they have not commonly been grown in the United States for feeding during the entire season. They have been used more often to supplement permanent pastures during a midsummer drouth or at any other time when the pastures provide insufficient feed. Even for this purpose, it has usually been much cheaper to grow such crops as Sudan grass to be used for temporary pasture, or to pasture the second crop on a hay field, or to feed silage or hay as the supplement to scanty pasture.

In case the pasture becomes parched and none of these other provisions has been made, it is certainly wise to cut and feed green some crop that has been raised in the regular rotation and which is ready for use at that time. Excellent crops for this purpose are green alfalfa, clover, the hay grasses, or corn.

In countries where labor is relatively cheap in comparison with the price of land, a much wider use is made of soiling crops than in this country. Soiling crops are used extensively, especially for dairy cows, in certain tropical and semitropical regions where large yields of green feed can be provided the year around by such a soiling crop as Napier grass.

By the use of a field chopper, or forage harvester, the time required for the daily harvesting of a soiling crop is much less than with the older methods, if a considerable number of animals are fed. Therefore, there is now renewed interest in the use of soiling crops, or "zero pasture," as it is sometimes called, for utilizing high-yielding forage crops. By successive cuttings, properly arranged, of such crops as alfalfa or a mixture of legumes and grasses, good feed can generally be provided throughout the season. Thus the expense and trouble of planting a special succession of crops for soilage is avoided.

387. Soiling crops vs. pasture.—Sufficient data are not yet available to show conclusively the relative economy under average conditions in this country of such use of soiling crops for dairy cattle or other stock, in comparison with well-managed pasturing, or with limited pasturage supplemented with silage or hay. To draw definite conclusions, complete data would be needed, including not only the production of milk or meat per acre with the different methods, but also accurate records of the labor cost and other expenses.

In a recent New Jersey trial with dairy cows, the milk production was maintained better on soiling crops than on pasture, but it required 3.1 hours a day to cut and haul the green feed for 50 cows.[46] In a Rhode Island experiment the milk production of cows fed soilage was appreciably higher than of others on pasture, and 22 per cent more milk was produced per acre.[47] In contrast with these results, in a Minnesota trial the milk production was no higher from cows fed alfalfa-bromegrass soilage than from cows grazed rotationally, but less area was needed per cow when soilage was fed.[48]

The gain of beef steers per acre of alfalfa was 69 per cent more in a California trial when the crop was fed as soilage than when the cattle were grazed rotationally.[49] The results were better when the alfalfa was fed fresh than when it was fed after wilting. In a Colorado test there was no significant difference in the gains of full-fed fattening cattle fed fresh-cut alfalfa, and of those fed alfalfa hay or grazing irrigated alfalfa.[50]

In pasturing a tall-growing crop, such as Sudan grass, there is a greater wastage of feed from trampling than on

an ordinary pasture, and consequently more advantage in feeding it as soilage. In a North Dakota trial the value of Sudan grass for sheep was about twice as great per acre when it was fed as soilage as when it was grazed.[51]

QUESTIONS

1. Why is pasturage usually the most economical feed for cattle, sheep, and horses during the growing season?
2. Discuss the influence of stage of maturity of forage crops on content of nutrients, considering the following: (a) Protein; (b) digestible nutrients; (c) phosphorus and calcium; (d) vitamins.
3. What is the effect of rate of growth and season of year on the composition of grass?
4. Give examples of marked differences between various pasture and hay plants in regard to the effect of advancing maturity on composition.
5. State 3 forage crops which are richest in nutrients when mature, and tell why this is so.
6. Why will immature forage, such as pasture grass, not fully take the place of concentrates in livestock feeding?
7. Discuss the composition of mature, weathered grass, and the effects upon stock receiving only such feed.
8. What is the effect of frequent cutting or continuous close grazing upon the total yield of dry matter by pasture or hay crops?
9. Discuss the influence of soil fertility on the composition of forage crops, considering content of protein, phosphorus, calcium, and vitamins.
10. Discuss the importance of pasture improvement.
11. State the essentials of proper grazing management to secure high pasture yields.
12. What are the advantages and disadvantages of rotation grazing for various kinds of stock?
13. What is strip grazing? Is this method used in your locality?
14. How should a run-down pasture be improved?
15. Explain the two general types of pasture fertilization. How would you decide which system to use on a particular farm?
16. Describe the intensive system of pasture fertilization and management, known as the Hohenheim system.
17. What methods can be used to provide good pasturage over a long season?
18. Discuss the nutritive value of fertilized and unfertilized forage.
19. How much has supplemental irrigation increased pasture yields in humid regions?
20. In what respects does the improvement of a range in the West differ from the improvement of pastures in a humid district?
21. What are soiling crops? Why is there now greater interest in the use of soiling crops than several years ago?

REFERENCES

1. Jennings, U.S.D.A. Cir. 836.
2. Hoglund, Mich. Spec. Bul. 390.
3. Semple and Woodward, U.S.D.A. Misc. Pub. 194.
4. Young, Ind. Bul. 359; see also: Ill. Cir. 649; Robbins, Ind. Cir. 376.
5. N.Y. (Cornell) Hay and Pasture Letter, No. 1; see also: Kearl, N.Y. (Cornell) Farm Economics, No. 198.
6. Bierly, N.Y. (Cornell) Farm Economics, No. 129.
7. Woodward, Shepherd, and Graves, U.S.D.A. Misc. Pub. 179; see also: Headley, Willhite, and Miller, Nev. Rpt. 1948.
8. For a review of such experiments see Huffman, Mich., Jour. Dairy Sci., 22, 1939, pp. 889–980; also see: Stanley and Hodgson, Ariz. Tech. Bul. 73; Colo. Rpts. 1944, 1945; Buckner and Henry, Ky. Bul. 473; Watkins, New Mex. Bul. 311; Watkins and Knox, New Mex., Jour. Anim. Sci., 4, 1945, pp. 297–305; Whitman, Bolin, and Klosterman, N.D. Bul. 370; Hobbs, Gallup, and Taylor, Okla., Jour. Anim. Sci., 4, 1945, pp. 395–402; Johnson et al., S.D. Bul. 412; Sanders, Tenn. Rpt. 1946; Fraps and Fudge, Tex. Buls. 582, 644, 669; Fraps and Fudge, Jour. Amer. Soc. Agron., 37, 1945, pp. 251–258; Stoddart and Greaves, Utah Bul. 305; McCall, Wash., Jour. Agr. Res., 58, 1939, pp. 603–616; Sotola, Wash., Jour. Agr. Res., 61, 1940, pp. 203–311; Burkitt, Wash., Jour. Agr. Res., 61, 1940, pp. 471–479; Savage and Heller, U.S.D.A. Tech. Bul. 943.
9. Ky. Rpt. 1947; Patton, Mont., Jour. Anim. Sci., 2, 1943, pp. 59–62; N. Mex. Rpt. 63; Kamstra, Moxon, and Bentley, Ohio, Jour. Anim. Sci., 14, 1955, p. 1238; Phillips and Goss, U.S.D.A., Jour. Agr. Res., 51, 1935, pp. 301–319; Phillips, Davis, and Weihe, Jour. Agr. Res., 64, 1942, pp. 533–546; Crampton and Forshaw, Macdonald College, Canada, Jour. Nutr., 19, 1946, pp. 161–172; Woodman, Jour. Min. Agr., Great Britain, 50, 1943, p. 43.
10. Watkins and Knox, N.M., Jour. Anim. Sci., 4, 1945, pp. 297–305.
11. Smith and Stanley, Ariz., Jour. Agr. Res., 56, 1938, pp. 69–71; Hauge, Ind., Jour. Assoc. Off. Agr. Chem., 17, 1934, pp. 304–307; Johnson, Peterson, and Brimhall, Iowa Rpt. 1948; Atkeson, Peterson, and Aldous, Kans., Jour. Dairy Sci., 20, 1937, pp. 557–562; Kuppers, Rusoff, and Seath, La., Jour. Agr. Res., 77, 1948, pp. 55–63; Snyder and

Moore, Mich., Jour. Dairy Sci., 23, 1940, pp. 363–371; Hathaway, Davis and Keim, Nebr. Res. Bul. 140; Watkins, New Mex., Jour. Agr. Res., 58, 1939, pp. 695–699; Hunt, Record, and Bethke, Ohio Bul. 576; Kemmerer and Fudge, Tex. Rpt. 1943.
12. Reid and Kennedy, N.Y. Farm Res., 16, 1950, No. 4; Hardison, Reid, and Martin, N.Y., Jour. Anim. Sci., 10, 1951, p. 1070.
13. Graves, Dawson, and Kopland, U.S.D.A. Tech. Bul. 649.
14. Peterson, Cal. Agr., 5, 1951, No. 8; Snider, Ill., Hoard's Dairyman, June 10, 1951; Harrison and Hodgson, Mich. and U.S.D.A., Jour. Amer. Soc. Agron., 28, 1936, pp. 447–456; Thomas, Hayes, and Schmid, Minn. Tech. Bul. 182; Newell and Keim, Nebr. Res. Bul. 150; Wakefield and Ahlgren, N.J. Rpt. 1950; Wiggans, N.Y. (Cornell) Bul. 424; Kennedy, N.Y. (Cornell) Memoir 295; Gardner et al., Penn. Bul. 323; Holt, Potts, and Fudge, Tex. Bul. 570; Newlander, Jones, and Ellenberger, Vt. Bul. 362; Aldous, Jour. Amer. Soc. Agron., 22, 1930, pp. 385–392; Wolfe, Jour. Amer. Soc. Agron., 18, 1926, pp. 381–384; Schutt, Hamilton, and Selwyn, Jour. Agr. Sci., England, 22, 1932, pp. 647–656; Davies and Sim, Australian Council Sci. and Indus., Res. Pamphlet 18.
15. Gardner et al., Penn. Bul. 323.
16. For reviews on this subject see: Beeson, U.S.D.A., Botanical Review, 12, 1946, pp. 424–455; Huffman, Mich., Jour. Dairy Sci., 22, 1939, pp. 889–980.
17. Fudge and Fraps, Tex. Bul. 644.
18. Sprague and Hawkins, N.J. Bul. 644; see also: Salisbury and Morrison, N.Y. (Cornell) Bul. 694.
19. Burton, Ga. Rpt. 1951; see also: Ramage et al., N.J., Jour. Anim. Sci., 13, 1954, p. 1011.
20. Excellent summaries on grassland improvement in various parts of the United States are given in: Burton, Sprague, and Harland, Jour. Agr. and Food Chem., 3, 1955, pp. 23–31; Stoddard, Smith, Humphrey, and Love, Jour. Agr. and Food Chem., 3, 1955, pp. 300–309.
21. Merrill and Young, Tex. Prog. Rpt. 1728.
22. Ahlgren, Sund, and Muckenhirn, Wis. Bul. 469.
23. Kaufman, N.C. Rpt. 1947; see also: Halls, Southwell, and Knox, Ga. Coastal Plain Bul. 51.
24. Stoddart and Smith, Range Management, pp. 383–392; Kirk, Fulford, and Hodges, Fla. Rpt. 1949; Halls, Southwell, and Knox, Ga. Coastal Plain Bul. 51; Smith, Anderson, and Baker, Kan. Cir. 308; Okla. Cir. C-125.
25. McKellar and Brown, Colo. Farm and Home Res., 3, 1952, No. 2; Cave and Atkeson, Kan. Rpt. 1936–38; Mich. Cir. Bul. 217; Pratt and Davis, Ohio, Jour. Dairy Sci., 37, 1954, p. 665; Williams, Sprague, Knodt, and Autrey, Penn., Jour. Dairy Sci., 30, 1947, pp. 572–573; Holdaway and Pratt, Va., Jour. Dairy Sci., 16, 1933, pp. 95–99; Mitchell and Wise, S.C., Jour. Dairy Sci., 27, 1944, pp. 189–196; Lundquist, Law, Ashworth, and Wolberg, Wash. Bul. 470; Wyo. Rpt. 60; Woodward, Shepherd, and Hein, U.S.D.A. Tech. Bul. 660.
26. Morrison and Ely, Ky. Rpts. 1943, 1944, 1945, 1946, 1947; Ahlgren, Rupel, Bohstedt, and Graul, Wis., Jour. Amer. Soc. Agron., 36, 1944, pp. 301–315.
27. Mayton, Rogers, and Grimes, Ala. Rpt. 1945–46; Ark. Bul. 443; Glasscock, Kirk, and Killinger, Fla. Rpt. 1949; Mott and King, Ind. Rpts. 1943, 1944; Scholl, McDonald, and Heady, Iowa Rpt. 1951, Part 1; Anderson, Kan. Bul. 291; Harvey, Burson, and Schmid, Minn. Farm and Home Sci., 11, 1954, No. 2; Comfort, Brown, and Hazen, Mo. Buls. 444, 477; Biswell and Foster, N.C. Bul. 360; Moore et al., N.C. Rpt. 1951; Whitman, Christensen, and Helgeson, N.D. Bul. 327; Blizzard, Hawkins, and Kiltz, Okla. Rpt. 1934–36; Hein and Cook, U.S.D.A. Tech. Bul. 538; Black and Clark, U.S.D.A. Cir. 642.
28. Fuelleman, Burlison, and Kammlade, Ill., Jour. Anim. Sci., 7, 1948, pp. 99–109; Ky. Rpt. 1947; Harrison, Cole, and Rather, Mich., Soil Sci. Amer. Proc., 6, 1941, pp. 303–308; Alexander and Newell, Nebr., Jour. Anim. Sci., 5, 1946, pp. 409–410.
29. Cal. Sta., Farm Journal, Feb. 1954.
30. Brundage and Peterson, Minn., Jour. Dairy Sci., 35, 1952, pp. 623–630; see also: Brundage, Alaska, Jour. Anim. Sci., 12, 1953, p. 939; Holmes, Waite, Ferguson, and MacLusky, Scotland, Jour. Agr. Sci., 42, 1952, pp. 304–313; Keilholz, Better Farming, June, 1955.
31. Ittner, Lofgreen, and Meyer, Cal., Jour. Anim. Sci., 13, 1954, pp. 37–43.
32. Hilton, Wilbur, and Mott. Ind. Cir. 290.
33. Ahlgren et al., Wis. Buls. 463, 469; see also: Pierre and Browning, Iowa Farm Sci. Reporter, 6, 1945, No. 3; Rather and Harrison, Mich. Cir. Bul. 189; Ensminger and McDonald, Wash. Bul. 410.
34. Ga. Coastal Plain Sta. Bul. 32; see also: Ga. Rpt. 1945.
35. Ahlgren, Muckenhirn, and Sand, Wis. Bul. 466; Graber, Wis. Cir. 277; Burcalow and Bohstedt, Wis. Cir. 298; see also: Cmarik, McKibben, and Cate, Ill., Jour. Anim. Sci., 14, 1955, pp. 1236–1237; Scholl, Hughes, and McWilliams, Iowa Farm Sci., 9, 1955, No. 9; Shepherd et al., U.S.D.A., Jour. Dairy Sci., 31, 1948, p. 697.
36. Ahlgren, Nielsen, Rupel, Bohstedt, and Graul, Wis. Bul. 463; see also: Cmarik, McKibben, and Cate, Ill., Jour. Anim. Sci., 14, 1955, pp. 1236–1237; Hughes and Scholl, Iowa Farm Sci., 5, 1951, No. 9; Shepherd et al., U.S.D.A., Jour. Dairy Sci., 31, 1948, p. 697.
37. Foley, Montague, and Parsons, Mass. Bul. 262; Archibald, Nelson, and Bennett, Mass., Jour. Agr. Res., 45, 1932, pp. 627–640; Bender, N.J. Buls. 564, 633; Salter and Yoder, Ohio Bimo. Bul. 152; Fink, Mortimer, and Truog, Wis. Bul. 421; Mortimer, Ahlgren, Graul, and Rupel, Wis. Bul. 428.
38. Ittner, Rendig, Ayers, and Weir, Cal. Agr., 7, 1953, No. 8.
39. Matrone et al., U.S.D.A. Tech. Bul. 1086.
40. Ore. Buls. 477, 491.
41. Dexter et al., Mich. Quar. Bul., 33, 1950, No. 3; Turk et al., Mich., Jour. Dairy Sci., 38, 1955, pp. 319–320; Headley, Nev. Rpt. 1946; Eheart and Pratt, Va. Tech. Bul. 81.
42. Autrey and Conniff, Ala. Rpts. 60–61; Ky. Rpts. 1949, 1951, 1952; Miss. Rpts. 65, 66; Prince, Blood, and Morrow, N.H. Bul. 402; Murley, Waugh, and Moore, N.C. Res. and Farming, 11, 1952, No. 1; Law, Beale, and Lund, S.C. Rpt. 64; Lush, VanHorn, Whitaker, and Throop, Tenn., Jour. Anim. Sci., 12, 1953, p. 940; Ewing, Tenn. Bul. 216; Hardison, Engel, Graf, and Linkous, Va., Jour. Dairy Sci., 37, 1954, p. 665.
43. Hopland, Post, and Stitt, Mont. Bul. 496; see

also: Rumery, Conard, and Adams, Nebr. Rpt. 63; Ore. Bul. 461; Hyer and Becker, Ore. Bul. 520; Bateman, Dew, and Stoddard, Utah Farm and Home Sci., 15, 1954, No. 1.

44. For further information on this subject see: Sampson, Range Management, Principles and Practices; Stoddart and Smith, Range Management; Barnes, Western Grazing Grounds; and the publications of the western experiment stations and of the United States Department of Agriculture.

45. McCandlish, Iowa Bul. 201; Frandsen et al., Nebr., Jour. Dairy Sci., 4, 1921, pp. 124–157; Woll, Humphrey, and Oosterhuis, Wis. Bul. 235; see also: Tretsven, Mont. Bul. 282.

46. Poulton, N.J. Agr., 35, 1953, No. 6; see also: Hogland, Mich. Quar. Bul. 37, 1955, No. 4.

47. Henderson and Cobble, R.I., Jour. Anim. Sci., 13, 1954, p. 1008; Rorholm and Henderson, R.I. Agr., 1, 1955, No. 3.

48. Gullickson, Livingston, and Jones, Minn. Farm and Home Sci., 11, 1954, No. 3; see also: Hoglund, Mich. Quar. Bul. 37, 1955, No. 4.

49. Ittner, Lofgreen, and Meyer, Cal., Jour. Anim. Sci., 13, 1954, pp. 37–43.

50. Connell, Colo. Farm and Home Res., 4, 1954, No. 6.

51. N.D. Bul. 396.

CHAPTER XIV

HAY AND HAYMAKING

I. Principles of Haymaking

388. Importance of efficiency in haymaking.—Throughout the temperate regions of the world hay is the most important harvested roughage for livestock. Very heavy losses of feeding value occur each year in this major crop, because hay is cured or stored improperly. Indeed, the losses in the hay crop are far greater than those in any other agricultural crop.

In addition to the waste of feeding value in poor hay, there is a huge loss each year through farm fires caused by spontaneous combustion. This waste, which is estimated at $30,000,000 or more a year in the United States, is due chiefly to the storage of hay when it contains an unsafe amount of water.

Most of these heavy losses can be prevented by efficient methods of haymaking, combined with good judgment. It is therefore important that every stockman understand clearly the principles which make possible high efficiency in haymaking.

The importance of the hay crop in the United States is shown by the fact that over 100,000,000 tons of hay are made a year from an average of about 73,800,000 acres. This annual hay crop has a farm value of nearly two billion dollars.

389. Characteristics of high-quality hay.—Since it is the object in haymaking to produce hay that has a high feeding value, let us first consider the characteristics of such hay. To be of high quality, hay must have been made from plants cut at a sufficiently early stage of maturity. Next, high-quality hay has been cured and handled so that it is leafy and green in color. The stems are soft and pliable. It is free from mustiness or mold. It is palatable, because of its fragrance and also because of its content of sugars and other soluble nutrients. It has but little foreign material, such as weeds or stubble.

Such hay is more nutritious and more palatable than that which does not possess these qualities, and it therefore has a much higher feeding value per ton. Indeed, there may be far more difference in actual value per ton between good and poor hay of any particular kind than there is between the different kinds of hay made from the various common hay crops. Most kinds of hay of the same grade or quality generally supply about the same amounts of total digestible nutrients, regardless of kind or variety. However, legume hay, such as alfalfa or clover, is of course much richer in protein, calcium, and vitamins than is grass hay of equal quality.

The Federal hay grades, by which hay is sold on the larger markets in the United States, are based on the qualities which good hay should have.[1] Any person who produces hay for such markets should familiarize himself with these grades, for the price paid for any lot of hay depends strictly on the quality as indicated by the Federal grade.

390. Usual grades of hay on farms.—To secure information on the grades of hay actually produced on northeastern farms, a 3-year study was made by the New Jersey Station and a 2-year study by the New York Station.[2] In these studies 2,567 samples of hay, mostly first cutting, were secured from farmers' barns during the winter feeding season and graded according to the official United States hay grades. On the average, 20 per cent of the lots of hay graded No. 1 (excellent hay), 45 per cent No. 2 (fairly good hay), 19 per cent No. 3 (rather poor hay), and 16 per cent Sample Grade, because of mustiness or mold, or being over-ripe or high in foreign mat-

ter. In the New York studies the average grade of the first cutting hay was 2.2, and of second-cutting hay, 1.8.

Probably the average grade of the hay fed on all the farms in the region would have been slightly lower than on the farms studied, because the least progressive farmers are less apt to cooperate in such investigations.

These and other studies show the need of improvement in haymaking, in order to secure the maximum feeding value from this important crop. The studies show that the chief factors in producing high-quality hay are cutting at the right stage of maturity, proper curing to retain leafiness and green color, control of foreign material, and storing only when the moisture has been reduced to a safe level.

391. Value of good and poor hay.—The great difference in feeding value between good hay and poor hay is well shown in recent experiments by the United States Department of Agriculture with dairy heifers.[3] During two winters one group of heifers was wintered on good alfalfa hay, U.S. No. 1 or 2, containing 23 to 27 per cent fiber. Another group was fed poor alfalfa hay, U.S. No. 3, having 33 to 34 per cent fiber. The heifers fed the good hay gained 28 per cent more and required 12 per cent less hay per 100 lbs. gain than those fed the poor hay.

Good and poor hay were also compared in a trial by the Ohio Station with steers full-fed corn-and-cob meal plus 1.5 lbs. of soybean oil meal per head daily.[4] Though these cattle, liberally fed on concentrates, did not eat an average of more than 2 lbs. of hay a day, nevertheless the quality of the hay made a difference of 0.3 lb. in the average daily gain. The difference in actual feeding value between the good and the poor hay was far greater than the $7.50 per ton difference in cost.

392. Importance of early cutting.—It has been shown in the previous chapter that the percentage of protein, the digestibility, and the content of minerals and vitamins all decrease decidedly as hay crops advance in stage of growth. (**358–362**) The rate of decrease in nutritive value tends to be more rapid in most grasses than in legume hay crops, such as alfalfa or clover.

Because of these changes in composition, hay that is cut late has considerably lower feeding value than that which is cut early, if the early-cut hay is cured equally well. Other factors than the nutritive value of the hay per ton must, however, be considered in deciding when to cut various crops for hay.

In humid regions it is usually much more difficult to cure the first cutting of hay satisfactorily, if it is cut extremely early. This is because of several factors. The plants then have a much higher percentage of water. They are also more hygroscopic,[5] and harder to dry, because of a greater content of sugars and other soluble nutrients. The soil is generally more moist early in the season, and the weather less suitable for rapid curing. There is more apt to be damage from rain.

Although early cutting considerably increases the feeding value of hay per ton, if it can be cured well, very early cutting may decidedly reduce the annual yield of dry matter. The smaller yield of a very early first cutting will usually be made up partly by a greater growth of aftermath, but the total yield of dry matter is frequently less. On the other hand, a higher yield of protein per acre is often secured by very early cutting.

An important fact is that repeated very early cutting of a tall-growing hay crop, especially alfalfa, is apt to reduce the stand seriously, because the plants die out due to depletion of nutrients in the roots. (**454**) Information is given in Chapters XVI and XVIII on the best stage for cutting various hay crops.

Experiments have shown that it is not necessary to cut a crop at an impractically early stage to secure hay of high feeding value. The chief decline in nutrients comes after the crop reaches full bloom, and especially when seed has developed. When one has a large acreage of hay, it is necessary to start haying

early enough to finish it before the last of the crop gets too mature.

The actual difference in feeding value per ton between hay cut in early bloom or before and that cut when the crop is in full bloom will depend on the class of stock to which it is to be fed. The difference is greatest where the hay is used as a vitamin supplement for swine or poultry. For this purpose, hay that is early-cut, leafy, and well-cured is essential, as the vitamin content is otherwise much lower. Early-cut hay should also always be used, if possible, for dairy calves and sheep. In storing the hay crop, some of the best hay should therefore be put where it will be accessible for these uses.

The difference in value between early-cut hay and that cut in full bloom is less for dairy cows and beef cattle, especially when silage is fed in addition to the hay, or when concentrates are fed liberally. For work horses or light horses hay cut when in bloom is preferred to that cut earlier, because hay cut extremely early is apt to be too laxative. Hay cut very late—in the seed stage or later—has a low value for all classes of stock.

When dairy cows were fed concentrates at a rather low rate with timothy hay as the only roughage, the milk production in New York trials on hay cut in the seed stage was only 59 per cent as much as on hay harvested when the timothy was heading out.[6] Also, the cows fed the late-cut hay lost 1.5 lbs. per head daily in weight, while those fed the early-cut hay gained 0.6 lb. a day. In another trial in which concentrates were fed liberally, 90 per cent as much milk was produced on the late-cut hay as on that cut early, but there was a difference of 1.1 lbs. a day in the gain in weight per cow.

Dairy heifers gained in weight and stored protein in their bodies in New Hampshire experiments when fed only timothy hay cut before bloom, but lost weight and protein on timothy hay cut in the seed stage.[7] Similarly, in Nebraska trials beef calves wintered on early-cut prairie hay made fair gains, but others fed prairie hay cut in September lost weight.[8] To produce as good results on the late-cut hay as on that cut early, it was necessary to feed one-half pound per head daily of protein supplement.

393. Reduction in water content.—The primary object in haymaking is to dry the green plants enough so that the hay can be safely stored without heating unduly or becoming moldy. For hay to keep safely in barn or stack, the water content must be reduced to not more than 25 per cent. If the hay is chopped or baled at time of storage the percentage of water should not be over about 22 per cent. Hay containing too much moisture when stored will undergo pronounced fermentation and become very hot. The value may be greatly decreased because of mold or the losses of nutrients which occur in the extensive fermentations. Also, there is always danger of spontaneous combustion when hay is stored with too much moisture. The slight fermentation, or sweating, that occurs in properly-cured hay when it is stored does not cause any marked loss of green color or nutrients. It even seems to improve the aroma and palatability of the hay.

Some believe that it is safer to store hay with a high moisture content when this is due to the moisture content of the plants, than when the hay has been dampened by rain or dew. It is not wise to rely on this. The only safe way to avoid serious loss is not to store any hay when it is too high in moisture, no matter what the cause.

A practical method used by farmers to find out when hay is cured sufficiently for storage is to twist a wisp of it in the hands. If the stems are slightly brittle and there is no evidence of moisture when the stems are twisted, the hay can be stored safely. In excellent curing weather the hay may appear drier than it really is, especially if cured chiefly in the swath. This is because the leaves will be dry and brittle, while the stems are still too high in moisture.

Among the various rapid methods devised for determining whether hay is dry enough for storage, one of the sim-

plest is the following, suggested by Dexter of the Michigan Station.[9]

A large representative handful is carefully selected and then bent or twisted to break the stems somewhat. From the center of the sample a portion is cut, approximately as long as a quart glass jar and sufficient to fill it loosely. The sample is placed in the jar, a teaspoonful of fine-grained table salt is added, and the cover placed on the jar. The sample should not fit so snugly as to prevent free circulation of the salt.

The jar is shaken about 100 times to keep the salt and hay moving about. Then the jar is held upside down and the salt is shaken into the cover, where it can be examined. If the hay is dry enough for safe storage, the salt will still be in small grains. On the other hand, if the hay has more than about 25 per cent water, the salt will have taken up moisture and be gathered in clumps. Samples that are distinctly too wet will change the salt in about 30 seconds. In border-line cases, the sample should be shaken again and allowed to stand for a few minutes.

The method may also be used for oats, barley, or wheat grain. Ten or more representative heads are threshed out, placed in a small container with about one-half teaspoonful of salt, and shaken about 50 times. The salt will stay dry if the grain has less than about 14 per cent water.

If it seems wise, because rain is threatening, to haul hay to the barn before it has reached the desired dryness, it should be spread out well in a mow to a depth not greater than about 3 to 5 feet. Special care should be taken not to leave any large, compact masses where the hay falls from the hay fork or sling. If possible, such hay should not be covered with other hay until it has cured out somewhat. The barn doors should be left open for ventilation.

394. Losses of nutrients in haymaking.—Some nutrients are always lost in the field-curing of hay, but under favorable conditions this loss is not large. However, the wastage may be great unless proper care is taken. These losses are not due to the mere drying out of the forage plants. Experiments have shown definitely that the drying of green grass or other green forage at ordinary temperatures does not reduce is digestibility.[10] Also, when plants are dried without any bleaching or fermentation, they have a high content of the vitamins that are of importance in stock feeding.

The losses that occur in haymaking are: (1) Losses of leaves and other finer parts by shattering; (2) losses by fermentation and bleaching; and (3) losses of soluble nutrients by leaching, in case of heavy rains.

395. Losses by shattering.—The leaves of legume hay dry out much sooner than the stems, and if they become dry and brittle they shatter badly when the hay is raked or otherwise handled. This loss of leaves is serious, for the leaves have 2 to 3 times as much protein as do the stems. They also contain most of the carotene and other vitamins, are much richer in minerals, and have much less fiber. The proportion of leaves is hence one of the most important factors in determining the feeding value of any particular lot of hay.

Legume hay, especially alfalfa, should therefore be raked before the leaves become dry. If the hay has dried out unduly before it is raked, it should, if possible, be raked early in the morning when it is damp with dew.

That the loss of leaves from alfalfa hay is large, even with modern haymaking methods, is shown by recent United States Department of Agriculture experiments.[11] An average of 38.5 per cent of the leaves of alfalfa was lost from field-cured hay in good weather with no rain, and as much as 74.5 per cent when the hay was wet by 3 showers. In very dry climates the loss by shattering may be even larger, unless great care is taken.

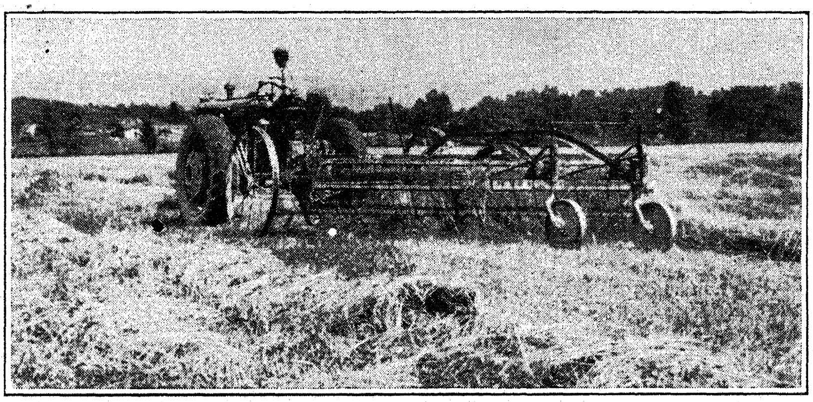
396. Losses by fermentations and bleaching.—Even in excellent haymaking weather, the curing of hay in the field is not merely a simple process of drying. Fermentations take place in which some of the organic nutrients, especially the sugars and starch, are oxidized to carbon dioxide and water, thus being lost. Also, fermentation has a very destructive effect on the carotene in hay. If the weather is favorable and the hay is cured by proper methods, without undergoing pronounced heating, the losses by fermentation will be relatively small.

However, rainy weather, which greatly prolongs the curing process, increases the losses. If very extensive fermentations take place, as in brown hay, a heavy loss of carbohydrates will occur and also the carotene and other vitamins will be largely destroyed. (412)

If hay is badly bleached by long exposure to the sun, nearly all the carotene will be lost. In general, the amount of carotene in hay is proportional to the greenness in color. Green-colored hay is nearly always rich in carotene and straw-colored or brown hay very poor in it.

However, unless the rain is so heavy that the hay is thoroughly soaked and washed by the rain, there will not be much loss by leaching. Also, severe leaching results only when the hay has dried out considerably before the rain comes. Hard rain soon after the crop is cut does not cause much loss.

398. Extent of total losses in hay.—The total loss of nutrients in hay during field curing and subsequent storage in the mow before feeding will vary widely. In fairly good haymaking weather and with proper methods, the



LOSSES OF NUTRIENTS REDUCED BY GOOD HAYMAKING METHODS

To produce high-quality hay, leafy and green in color, hay should be raked into small, loose windrows, after it has partly cured in the swath. (From New York State College of Agriculture, Cornell University.)

The losses by fermentation do not cease when hay is stored in the barn. If the hay is well dried and does not heat unduly in the mow, the loss of dry matter in barn storage for 6 months will usually not exceed 5 to 7 per cent. When hay is under-cured and molding or severe heating occurs, the loss is much greater. As has been shown in Chapter VII, a continual loss of carotene takes place in hay during storage. (195)

397. Loss by leaching.—If hay that is already nearly cured is exposed to heavy and prolonged rain, especially when it is in the swath, severe losses may occur through leaching.[12] At least 20 per cent of the protein and considerably more of the nitrogen-free extract may thus be lost by leaching.

total loss of dry matter from the green crop to the manger should not exceed 20 to 30 per cent for legume hay and 10 to 15 per cent for grass hay. Under unfavorable conditions the loss will be considerably higher.

Extensive experiments have been conducted by the United States Department of Agriculture and at Cornell University and the University of Vermont to study the losses of dry matter and nutrients in various methods of handling hay crops.[13] Similar studies have also been made at other institutions.[14] In the United States Department of Agriculture investigations with 7 harvests of first-cutting alfalfa, the total loss of dry matter in field-cured hay, from the time it was cut in the field until it was fed in winter,

averaged 21.0 per cent when the hay was not rained on and 36.6 per cent when there were rains during curing. Most of this loss occurred before the hay was stored, the loss of dry matter during storage being not over 4 per cent.

The total loss of dry matter in barn-dried hay, from cutting to feeding, averaged 19.0 per cent when the air was not heated and only 15.2 per cent with heated air.

The total loss of dry matter was least for dehydrated hay, the loss from cutting to feeding being only 9.7 per cent. Wilted silage ranked low in total loss of dry matter, the average being 16.8 per cent, of which 11.0 per cent occurred in the silo.

The losses of protein and of total digestible nutrients were somewhat greater than for dry matter. On the average, 27.7 per cent of the protein and 25.5 per cent of the total digestible nutrients were lost in field-cured hay in good weather; 24.0 per cent of both protein and total digestible nutrients in barn-cured hay without heated air; 18.2 per cent of the protein and 13.1 per cent of the total digestible nutrients in dehydrated hay; and 16.9 per cent of the protein and 19.5 per cent of the total digestible nutrients in wilted silage.

The losses of carotene were very heavy in all methods. Even in dehydrated hay 76 per cent of the carotene was lost from cutting to feeding. The loss for wilted silage was 81 per cent; for barn-dried hay (no heat), 94 per cent; for barn-dried hay (heated air), 90 per cent; and for field-cured hay (good weather), 97 per cent. In spite of these very great losses, the original carotene content of the green alfalfa was so high that even the field-cured hay made in good weather had plenty of carotene, when fed, to meet the vitamin A needs of dairy cows. On the other hand, the field-cured hay that was rained on was deficient in carotene.

The carotene content per pound of dry matter of the alfalfa when fed was: wilted silage, 28.1 mg. (milligrams); dehydrated hay, 26.0 mg.; barn-dried hay (heated air), 14.2 mg.; barn-dried hay (air not heated), 9.3 mg.; field-cured hay (good weather), 5.4 mg.; and field-cured hay (rained on), only 1.7 mg.

II. Haymaking Methods

399. Modern methods of curing hay.—Several experiment stations have conducted investigations to find the most economical methods of making good hay, especially legume hay.[15] The most important results of these experiments are summarized in the following articles. These studies have shown that proper equipment not only greatly decreases the labor cost, but also is important in improving the quality of the hay.

The experiments have shown that hay dries much more rapidly in the swath than in the windrow, even if the windrow is small and loose. However, claims are often made to the contrary. The larger the windrow is, the slower will be the curing, and the rate is still slower in cocks.

Though hay cures rapidly in the swath, it is not advisable to cure it entirely there, except perhaps with grass hay in cool, dry weather. When curing is completed in the swath, the leaves become dry and brittle long before the stems have dried out sufficiently. With legume hay, especially alfalfa, a heavy loss by shattering of the leaves will then take place when the hay is handled. Also, the prolonged exposure to the sunlight will bleach the hay and destroy much of the carotene.

On the other hand, if the green forage is raked into a windrow, even a small, loose one, immediately after it is mowed, an unduly long time will be needed for curing, except in a very dry climate. Fermentation and molding may occur, which will seriously damage the hay. Such slow curing also increases the risk of damage from rain.

For the production of high-quality hay, leafy and green in color, with a minimum of labor, the following method is generally best: First, even if there is a dew in the morning, experiments have shown that there is no advantage in delaying mowing until the dew has dried off. In most cases, hay mowed early in

the morning will be drier by afternoon than that which has been cut later in the day. No more hay should be mowed at a time than can be taken care of properly under usual weather conditions.

After mowing, let the crop lie in the swath for a few hours, until it is partly cured. Before there is danger of the leaves shattering, rake it into small, loose windrows, preferably with a side-delivery rake. As long as the leaves remain alive, they may perhaps help to dry out the stems, by pulling water from them as the leaves evaporate it.[16]

mower, to crush the stems and hasten the drying. After the crushing, the hay is dropped to the ground and cured in the usual manner. Tests have shown that the curing time is usually reduced decidedly by crushing.[17] However, the high cost of the equipment is a deterrent to its use, except on farms where there is a large acreage of hay.

400. Curing hay in cocks.—Before the modern, labor-saving methods of making hay were developed, it was generally advised that to make hay of the best quality, regardless of expense, it

CURING HAY IN COCKS REQUIRES MUCH LABOR

The color and carotene content are well preserved when hay is put in well-made cocks as soon as it has dried enough so that it will not mold. However, this method requires too much labor for use on any large acreage.

should be put in well-made cocks as soon as it had dried enough so it would not heat or mold. This method preserves the color and carotene content, but it requires too much labor for use when there is any considerable acreage. Also, in a humid climate there is much risk of damage from rain before the cocks dry out, unless one goes to the further considerable expense of covering the cocks with hay caps. Therefore the cocking of hay is not now a common practice in most sections of this country.

However, it is probably wise to cock hay sometimes to lessen damage from rain. Hay is injured most by heavy rain when it is nearly cured. Therefore, if there is every prospect of a hard storm

If good weather continues, the curing should be completed in the windrow and the hay hauled to the barn or stack directly from the windrow. To avoid serious loss of leaves in dry climates, it may be necessary to handle the hay only early in the morning before it has become too dry.

When the weather is such that the hay cures rather slowly, it may be advisable in a few hours to turn the windrows partly over, in order to hasten the curing. Turning may also be necessary if the hay is wet by rain when in the windrow.

Hay crushers have been developed which pass the forage between rollers after it is cut by the cutter bar of the

at that time, it is a good plan to hurry and put the hay into large, well-made cocks. Unless the rain is unusually heavy, these will not wet through, there will be practically no loss from leaching, and the color and carotene content will be well preserved. When the weather clears and the outside of the cocks has dried, it may be necessary to open them somewhat to dry out the interior before the hay is stored.

401. Curing devices for very rainy districts.—In some sections of northern Europe, especially in Scotland, Norway, Sweden, and Finland, where the summer weather is cool, the humidity high, and rain very frequent, it is nearly impossible to cure hay satisfactorily in the field by ordinary methods. In these regions, after the hay is partly cured, it is generally put on tripods or other devices which allow the air to penetrate.

Similar methods are used to some extent in this country, especially in curing cowpea hay or peanuts in the southeastern states. All of these methods take much labor and are too expensive to be used where good hay can generally be made by ordinary methods.

A common method under such conditions is to cock the hay, after it is partly cured, on tripods, where it is left until dry enough for storage. The tripod consists of 3 poles, joined at the top, and generally with cross pieces at right angles to keep the hay off the ground. This permits making a large, well-ventilated cock that will contain as much as 500 lbs. or more of hay after curing. Sometimes single poles with crosspieces near the bottom are used instead of tripods. These are set in holes made in the ground. This method is often used in curing peanuts in this country. Another method used in some sections of northern Europe is to drape the hay in layers over the wires of temporary fences put up in the hay field.

402. From windrow to storage.—Several methods are used in getting hay from the windrow to storage. These include the hay-loader method, buck rakes, windrow balers, and field choppers, with the other equipment used in connection with these machines. Several experiment stations have conducted cost studies to determine the amounts of labor required and the other expenses per ton in handling hay by the various methods.[18] In these experiments the hay-loader method has generally been taken as the standard with which the newer methods have been compared. Some of the important results of these studies are summarized in the following articles.

No matter what method is used in handling and storing hay, good judgment should be used in putting the various kinds and qualities of hay in a place where they will be available when wanted, and not be covered with other hay. On a dairy farm, it is a mistake to put all the late-cut hay on top of the higher-quality, early-cut hay. If this is done, the cows may drop off severely in production in the fall when they get only the poorer hay.

403. The hay-loader method.—In the northeastern and north-central states the hay-loader method of handling hay is still common. When the hay is loaded with a hay loader, it is generally unloaded at the barn with a hay fork or hay slings and mowed away by hand. Sometimes the hay is run through a stationary hay chopper or silage cutter at the barn and blown into the barn. Occasionally, the long hay is blown into the mow by means of a hay blower, either manufactured for the purpose or converted from the blower on an old threshing machine.

When the hay is unloaded with a hay fork or slings, care should be taken to distribute it well in the mow and not leave it in large, compact masses where it falls from the fork or sling. Such masses are especially apt to heat badly, if the hay is not thoroughly dry.

The hay-loader method requires somewhat more man labor per ton than some of the newer methods, but the cost of equipment is much lower than with a windrow baler or field chopper. Except when the acreage of hay is large, the total cost per ton of handling hay by the hay-loader method may therefore be less

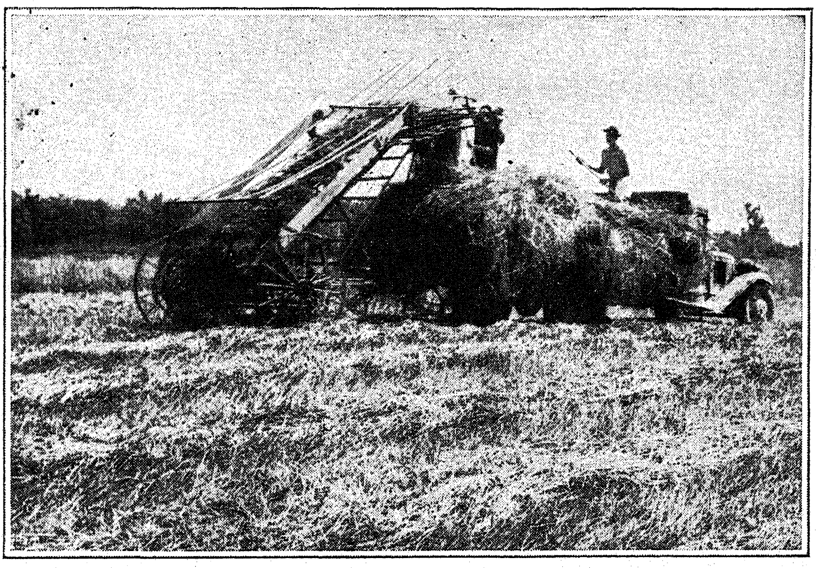
than when a field chopper or windrow baler is used.

Pitching hay on a load by hand requires more man labor per ton than loading it with a hay loader, and it is also much harder work.

404. The buck-rake, or sweep-rake method.—In the Great Plains and westward much hay is hauled from the windrow with buck rakes, or sweep rakes. Commonly the hay is stacked in the field by hay stackers or other mechanical devices. Some farmers in the sections of the country where hay is stored in barns or sheds also use the buck-rake method of handling hay. The hay is gathered up from the windrow with the buck rake and hauled on it to the place where it is to be stored. Here it is put in the mow with hay sling, grapple fork, or blower. The hay is too loose for successful use of a harpoon hay fork.

Where the distance from the hayfield to the storage place is not long, the buck rake is the cheapest method of handling hay. The amount of labor per ton is small and the cost of equipment is relatively low.

405. Baling hay from the windrow.—During recent years the baling of hay from the windrow with windrow balers, or pick-up balers, has greatly increased in this country. In some districts much hay is now baled from the windrow by custom balers. Hay of good quality, free from mold and of good color, can be made with the windrow baler if certain precautions are taken.



THE HAY-LOADER METHOD IS EFFICIENT

The hay-loader method of handling hay requires somewhat more man labor per ton than when a one-man windrow baler or a field chopper is used. However, this is offset by the low cost of equipment. (From New York State College of Agriculture, Cornell University.)

The hay should preferably be a little drier than is safe for storage of loose hay in a large mass.[19] The hay should certainly not contain more than 25 per cent water, and 20 to 22 per cent is better. If legume hay gets too dry before it is baled, the leaves will shatter badly. Otherwise, windrow baling saves the leaves well.

The hay must not be packed so tightly in the bales as is customary in baling hay that has gone through the

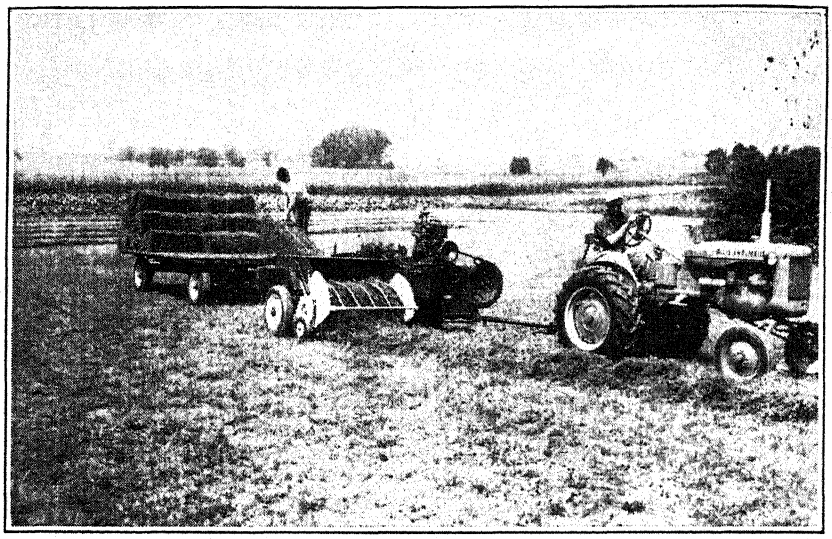
"sweat" in mow or stack. With a moisture content of 25 per cent, the bales should not weigh more than 8 lbs. per cubic foot. Drier hay can be packed a little tighter.

To allow ventilation in the pile of bales in a mow, rectangular bales should be placed on edge, with the fold edge of one bale next to the chaff edge of the next one and with the alternate layers at right angles. The bales should not be crowded closely together, but it is not necessary to leave a large space between them. All loose hay should be removed from the top of a layer of bales before the next layer is placed on it.

With the one-man balers the labor cost is somewhat less than with the hay-loader method, but because of the much greater investment, the total cost per ton may be higher, unless the acreage of hay is large. Where baled hay is to be sold, the windrow baler is especially advantageous.

Instead of lifting the bales by hand and loading them onto the truck, much labor can be saved by means of a bale chute, which delivers the bales to a truck towed behind the baler. Another way of saving labor in loading bales is by means of a bale loader. At the barn, time and hard work can be saved by the use of a bale elevator.

In the irrigated districts of the Southwest it is often difficult to prevent alfalfa hay from becoming so dry in the field that it shatters badly. High-quality hay may be made by putting it in large cocks while still tough, and then baling it from the cocks with a portable baler after it has cured sufficiently.



ONE-MAN WINDROW BALER SAVES LABOR

A one-man windrow baler with a device for loading the bales direct from the baler. (From New Holland Machine Co.)

406. Danger from baling wire.—In handling and feeding hay baled with wire, great care is necessary to prevent losses of cattle from baling-wire injury. Sharp pieces of wire consumed with the hay often may pierce the stomach and damage the heart or other vital organs. Cutting the wires should be avoided if possible. With windrow-baled hay the bales shrink sufficiently in curing so that the wires can easily be pulled off.

The wires should be put in a barrel or box, where they will not get into feed or manure. If wires get into the manure, they may be cut into dangerous pieces by the mower when a hay crop is harvested later.

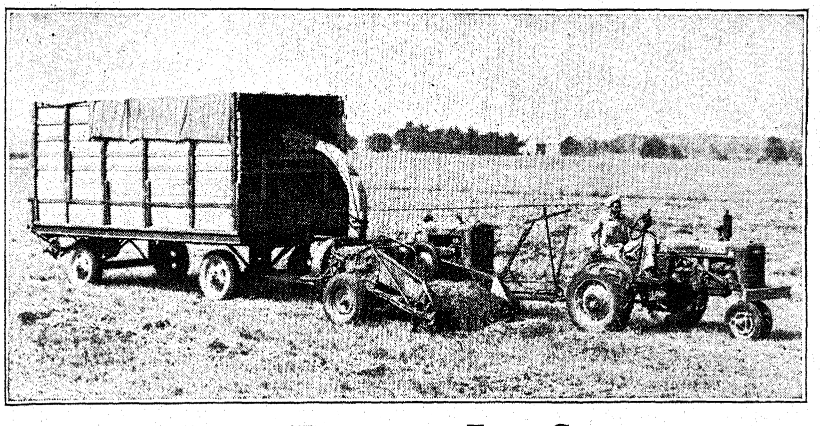
407. Chopping hay.—During recent years the use of field choppers, or forage harvesters, for handling hay from the windrow has greatly increased. The chopped hay is blown into a truck alongside or towed behind the chopper, and then at the barn is blown into the mow with a special blower. In semi-arid districts the chopped hay is often stacked in the open. Sometimes long hay is taken from the windrow to the barn and there chopped with a hay chopper or silage cutter which blows it into the mow.

Chopped hay is convenient to feed. However, the feeding value per ton of good-quality hay for cattle, sheep, or horses is not increased appreciably by chopping it, if the hay is fed in mangers or racks that prevent undue wastage. (92) There may be somewhat more advantage in chopping poorer hay.

Hay chopped fine is dusty and is much less palatable to cattle, sheep, or horses than hay chopped coarsely. Also, more power is required to chop hay fine, and the hay is more apt to heat badly when stored. Therefore the chopper should be set to chop the hay as coarse as possible.

For safe storage, chopped hay must be a little drier than is necessary with long hay. It has a greater tendency to heat unduly, because it packs much more densely and there is less opportunity for moisture and heat to escape. Chopped hay occupies only one-half to one-third as much space as long hay, and thus barn storage space is saved. However, care is necessary not to overload the joists in storing chopped hay, unless the barn has been built especially for such storage.

The hay should be distributed in the mow by adjusting the blower. It should never be tramped or packed, but should be allowed to settle itself. Otherwise, it is apt to heat in spots.



HANDLING HAY WITH A FIELD CHOPPER

When a field chopper is used, with suitable equipment for hauling and unloading the chopped hay, the amount of labor required per ton is very low. However, the cost of the equipment is high.

When a field chopper is used with suitable equipment for hauling and unloading the chopped hay, the amount of labor required per ton is very low. Though the investment in equipment is high, this method is economical when the acreage of forage handled by the chopper is sufficiently large to justify the expense. The cost per ton is reduced materially when a forage harvester is used not only to handle the hay, but also to harvest hay crops or corn for silage.

Chopped hay should not be stored in ordinary silos, unless it is considerably dryer than would be necessary in the case of uncut hay stored in a mow or

stack. Otherwise, it is apt to heat greatly and it may even char.

408. Barn-drying hay.—In areas where the weather is such that it is frequently difficult to make field-cured hay of good quality, the barn-drying method is often used. In this method partly-cured hay is dried by blowing unheated or heated air through it. A powerful fan blows air from outside the barn into a large duct constructed on the floor of the mow. From this, the air passes between the floor of the mow and a false slatted floor above it, or into a system of ducts or flues on the floor, and thence up into the mass of hay. This method is used both for partly dried long hay and for chopped hay. Sometimes baled hay is cured thus.

In this method the hay should, if possible, be at least half cured in the field, to bring the water content down to not more than 40 per cent. In suitable weather, it is better to cure it even a little more than this in the field, because it lessens the weight that must be handled and reduces the cost of power in barn drying. Hay with 35 per cent water is tough enough so that few leaves shatter.

Unless the curing is completed in a week or less, the barn-dried hay is apt to mold. It is therefore important to have a fan with plenty of air capacity. With a system that is properly constructed and operated, there is no danger of spontaneous combustion, as the temperature does not rise to a dangerous point.

In most barn driers the fan is driven by an electric motor. It is well to have the installation made so that the fan can also be run with a tractor in case there is a serious interruption of electric power.

In regions where the air is very humid at night, much better results are secured when the air is heated somewhat by an oil furnace or other means. This increases the cost, but makes it possible to obtain satisfactory results under difficult weather conditions.

In bad weather for haymaking, better hay can usually be made by this system than by ordinary field-curing methods. Satisfactory hay may even be made under conditions where it would be severely damaged or nearly worthless if field cured. On the other hand, in good hay-making weather, there is generally but little difference in quality between barn-dried and field-cured hay, except that barn-dried legume hay is apt to be more leafy and higher in protein, because it is stored before the leaves tend to shatter.

The advantages of the barn-drying method are more or less offset by the considerably increased cost, because of the expense of the equipment, the cost of power, and the increased labor in handling the heavy, partly-dried hay. Also, the capacity of a barn for storing hay is much lessened in this method, because the hay must not be stored in too great depth.

In bad haymaking weather, it is probably cheaper as a rule to make a hay crop into silage than to use the barn-drying method. The feeding value of the crop, especially the carotene content, is preserved even better in hay-crop silage. Also, good silage can be made when rains are so frequent that it would be difficult to cure hay in the field sufficiently for barn drying.

Barn-drying with unheated air does not avoid an appreciable loss of nutrients by fermentation during the curing process in the mow. In fact, a large part of the heat needed to evaporate the excess water from the partly-cured hay comes from the oxidation of nutrients that takes place. In tests by the United States Department of Agriculture, hay stored with 39 per cent of water lost 9.9 per cent of its dry matter in barn drying.[20] The loss was only 5.7 per cent with hay having 33 per cent of water. In New York trials the loss of dry matter in hay during barn drying and storage was 6.7 per cent.[21]

The carotene content of barn-dried hay is much higher when placed in the mow than for field-cured hay, but a large part is lost in the drying process through the fermentations, and later during storage. When fed in the winter, barn-dried hay will, however, usually have consid-

erably more carotene than field-cured hay cut at the same time. For example, in 6 lots of hay made at Cornell University, barn-dried hay cured without heat had 8.4 milligrams of carotene per pound of dry matter when fed in winter, while field-cured hay had only 3.8 milligrams.[21] In similar studies by the United States Department of Agriculture, barn-dried hay, air not heated, had 9.3 milligrams of carotene per pound of dry matter when fed, and field-cured hay 5.4 milligrams.[22] Though the carotene content of the field-cured hay was much lower in both studies, nevertheless it still had plenty to meet the needs of dairy cows.

409. Feeding experiments with barn-dried hay.—The comparisons of the value of barn-dried hay with that of field-cured hay made in reasonably good weather from the same crop and cut at the same time have shown that there is usually little, if any, difference in the palatability and the actual feeding value of the two kinds of hay per pound. The advantages of barn-drying are therefore the following:

Barn-drying helps to take the gamble out of hay making in humid regions, especially in making the first cutting of hay. It is hence possible to make hay of good quality earlier in the season than by field curing. Such earlier-cut hay definitely has a higher value per ton than field-cured hay made later. Also, as has been pointed out previously, the nutrient losses and the losses of dry matter are somewhat less than in field curing, even in good weather. Thus, somewhat more hay is secured per acre for feeding. These advantages can also be secured when the crop is made into silage by good methods.

410. Barn-dried hay for dairy cattle.—Barn-dried alfalfa or mixed grass-and-legume hay was compared with field-cured hay, made from the same crop and cut at the same time, in 6 New York experiments.[21] The same amount of concentrates was fed with the two types of hay. At the time of feeding, the barn-dried hay was generally greener in color, and it usually graded about one U.S. Grade higher than the field-cured hay. There was no appreciable difference in the palatability of the hays, and on the average the cows ate fully as much hay when fed the field-cured hay. The daily yield of 4 per cent fat-corrected milk averaged 31.5 lbs. on the barn-dried hay and 31.1 lbs. on the field-cured hay.

In 4 of the trials field-cured windrow-baled hay was compared with the other hays. There was no significant difference in hay consumption or in milk production on the different types of hay.

In experiments during 3 years by the United States Department of Agriculture, alfalfa was made into barn-dried hay, field-cured hay, and wilted alfalfa silage.[22] One year the field-cured hay was damaged somewhat by rain, but the weather was favorable for hay making in the other seasons. The good field-cured hay was as satisfactory for dairy cows as the barn-dried hay or the alfalfa silage, but the field-cured hay that had been damaged by rain was lower in value.

In these studies, which extended over 6 crops, 81 per cent of the original dry matter in the alfalfa was saved for feeding by barn drying without heat, 85 per cent by barn drying with heated air, 82 per cent by ensiling the crop, 79 per cent by field curing in good weather, and only 63 per cent by field curing in bad weather.

Similar results have usually been secured in experiments with dairy cows by the Indiana, Massachusetts, Michigan, and Virginia Stations,[23] and in trials with dairy heifers by the Maine, Ohio, Tennessee, and Vermont Stations.[24] In a Michigan trial in which the barn-dried hay was cut 2 weeks earlier than the field-cured hay, it was definitely superior to it.[25]

411. Barn-dried hay for other stock.—Field-cured hay was fully equal to barn-dried hay for wintering beef steers in a Maine trial.[26] In a Nebraska experiment field-cured alfalfa hay gave about as good results as barn-dried alfalfa or dehydrated alfalfa pellets when fed as the protein supplement for wintering beef calves.[27]

Colts in an Iowa test decidedly preferred barn-dried hay to field-cured hay that had heated badly in storage and had become musty.[28]

412. Brown hay.—Several years ago there was interest among farmers in making "brown hay" when weather conditions were unfavorable for making good hay by the usual methods. Because of the very heavy losses of nutrients in brown hay, and the uncertainty of securing a fair product, most of the brown hay now made in this country is produced accidently, and not intentionally.

In this method the forage is allowed to wilt until the water content has been reduced to about 50 per cent and then is well packed in a stack. Extensive fermentation occurs and much heat is developed. If all goes well, the temperature does not rise above 175° F., and the heat drives off the water in the mass.

The loss of dry matter in the fermentations is often as high as 40 per cent, and the digestibility is much decreased.[29] The product will vary in color from dark brown to nearly black, depending on the degree of fermentation. The darker the color, the lower is the feeding value. Hay that is nearly black is worth but little.

Brown hay of good quality is well liked by stock, but it is very low in vitamins, and should therefore not be the only roughage for stock throughout the entire winter. In experiments brown alfalfa hay was about equal to good green alfalfa hay for fattening steers and fattening lambs, but it was distinctly inferior to green alfalfa hay for dairy cows.[30]

413. Salting hay; so-called "preservatives."—Some farmers believe that sprinkling 10 to 20 lbs. of salt on each ton of rather-damp hay helps to prevent mold or undue heating. Salting may perhaps make poor hay somewhat more palatable, but experiments have shown that it is no insurance against spoilage, or even against spontaneous combustion if the hay is much too damp.[31] In fact, too great reliance on salting may be dangerous. The only safe plan is not to store hay unless it is dry enough for safety.

So-called "preservatives," consisting chiefly of ordinary baking soda, have been sold with claims that, due to liberation of carbon dioxide, all heating or molding would be prevented by sprinkling 1 to 5 lbs. of the compound on each ton of under-cured hay or threshed grain. There is no sound basis for such claims, because in the normal heating of new hay or grain when stored, a far greater amount of carbon dioxide is produced than could be formed from the small quantity of the "preservative."

In experiment station tests of such compounds, they have not reduced the spoilage of damp hay.[32]

414. Spontaneous combustion.—If hay or other dry forage containing too much moisture is put into a mow or stack, rapid fermentations take place in which a large amount of heat is produced. In a large mow or stack most of this heat is retained in the mass, causing a rapid rise of temperature. In these fermentations highly unstable organic compounds are apparently formed which are readily oxidized.[33]

At temperatures of 150° to 175° F. all bacteria or molds are killed or made inactive, but the oxidations continue, and the mass may become extremely hot. Finally, the hay begins to char and spontaneous combustion may occur and the mass burst into flames. This generally happens a month or 6 weeks after the hay is stored, but it may occur sooner.

The only way to avoid such loss is never to store hay in a large mass unless it is thoroughly cured. Chopped hay must be drier than long hay for safe storage. For safety, mows should be inspected at least twice a week during the first 2 months after the hay is stored. If hay in a mow or stock heats badly within 2 or 3 days after storing, and pungent odors, with much vapor, are given off, it should be removed at once and spread out to dry. Removing the hay later may only hasten spontaneous combustion.

If danger threatens, it is wise to take the temperature down in the hot

spots in the hay, by lowering, in a pipe driven into the hay, a thermometer that reads up to 200° F. If the temperature goes above 160° F., there is grave danger, and at 175° to 185° fire pockets may be expected. Before removing the hay then, a fire department should be called, if available, for the hay may burst into flame when the air reaches it.

Injecting into a mass of hot hay carbon-dioxide gas under pressure, from a cylinder of the compressed gas, such as is used in soda fountains, or from dry ice, cools the hay and helps prevent fire.

Stacks should never be built on old, rotten stack bottoms. Baled hay, grain in the sheaf, or other heavy material should not be put on top of hay in a mow which is going through the sweat, for it will prevent the escape of heat and gases. Crops upon which rain has fallen should receive extra care, and should not be housed until completely dry.

415. Measurement and shrinkage of hay.—Farmers, ranchers, and hay dealers buy and sell large quantities of hay in the stack according to the estimated weight. The stack is measured and the volume and tonnage are then computed by one of several rules in common use. The density of the hay and therefore the number of cubic feet required per ton are affected by many factors. Hay that was stored when slightly damp will be more compact than that which was very dry. The coarseness of the hay also affects its density.

The following rules are recommended by the United States Department of Agriculture for estimating the tonnage of hay in stacks, from the volume in cubic feet.[34] For hay 30 to 90 days in the stack, 485 cubic feet per ton for alfalfa; 640 for timothy and timothy mixed hay; and 600 for wild hay. For hay over 90 days in the stack, 470 cubic feet per ton for alfalfa; 625 for timothy and timothy mixed hay; and 450 for wild hay. The same approximate figures may be used for hay in a mow. In Idaho tests only about 150 cubic feet of stacked chopped alfalfa hay were required to make a ton.[35]

The volume of hay in a mow can readily be computed, but it is more difficult to determine the volume of a stack. Different rules for estimating this have been used in various sections of the country. The following are recommended by the United States Department of Agriculture after much investigation on the subject:[34]

The volume of a rectangular or oblong stack in cubic feet is:

For low, round-topped stacks:
$$(0.52 \times O) - (0.44 \times W) \times W \times L$$
For high, round-topped stacks:
$$(0.52 \times O) - (0.46 \times W) \times W \times L$$
For square, flat-topped stacks:
$$(0.56 \times O) - (0.55 \times W) \times W \times L$$
The volume of a round stack is:
$$(0.04 \times O) - (0.012 \times C) \times C^2$$

In these formulas O is the "over" (the distance from the base on one side of the stack, over the stack, and to the base on the other side); W is the width; L is the length; and C is the circumference of a round stack, or the distance around it. In measuring a round stack, the "over" should be an average of two measurements made at right angles to each other.

Hay stored in the mow will shrink in weight, due to drying out and also to fermentations taking place during the sweating process, in which nutrients are broken down into carbon dioxide and water. The shrinkage in weight will vary, depending on the water content of the hay when placed in the mow, and may reach 20 per cent or over. The losses of dry matter in hay during storage have been discussed previously. (**396**)

When hay is stacked, the shrinkage in weight is greater than in a mow, since the outside of the stack is exposed to the weather. A stack 12 feet in diameter has about one-third of its contents in the surface foot.

The difference in the loss of dry matter in stacked hay and in that stored under cover will depend on how well the stack is made, on its size, and especially on the climatic conditions. West Virginia trials show that in hay stored in well made stacks until winter the loss of dry matter was not much greater than

in hay stored in a barn, and the feeding value per ton of hay fed was nearly as high.[36]

III. Dehydrated Hay or Other Forage

416. Dehydrated hay.—More than a million tons of dehydrated hay, mostly alfalfa, are now produced commercially each year in this country. This dehydrated hay, made in dryers of various types, is used chiefly as a vitamin supplement in rations for poultry and swine, and to a lesser extent in calf meals and for other stock. In addition to alfalfa, other hay crops or other forages are sometimes dehydrated for these purposes.

The forage is first chopped and then passed through the drier. Here it is exposed by various methods to a current of hot air or a mixture of hot air and gases from an oil burner or furnace. Sometimes the green material is partly dried in the field to reduce the cost of dehydrating it, but this lowers the carotene content somewhat.

Though the temperature of the hot gases may be over 1,000° F., the forage itself does not become so hot as to be injured in a good drier. This is due to the cooling effect produced when the water evaporates from the plant tissues. In this method there is no loss of leaves, and therefore a maximum yield of dry matter and of protein and other nutrients is secured. The green color is also well retained.

Dehydration preserves the feeding value of a hay crop decidedly better than making it into field-cured hay or even making it into barn-dried hay or silage. However, the cost per ton of dry material is much higher. This is because of the large cost of the dehydrating plant, the considerable amount of fuel required for each ton of dried hay, and the expense for power and labor. Where good hay can be made by ordinary methods, it is therefore not usually economical to dehydrate hay crops for feeding to dairy cattle, beef cattle, sheep, or horses. In regions where rains are so frequent in summer that much of the field-cured hay is damaged, in spite of good management, it is generally much cheaper to make hay crops into silage, or to use a barn-drying method.

In experiments at the Vermont Station there was a loss of only 5.5 per cent of the dry matter in dehydrating hay and storing it until winter.[37] When the same crops were cured in the field in reasonably good weather and stored until winter, 23.4 per cent of the dry matter was lost in the case of legume hay and 9.5 per cent with timothy hay.

In recent experiments by the United States Department of Agriculture the loss of dry matter in dehydrated alfalfa from field to manger in the winter was only 3.3 per cent when the dehydrator was operating properly.[22] Compared with this, the average loss in field-cured hay, made in good weather, was 21 per cent; in barn-dried hay with heated air 15 per cent; and in wilted silage 17 per cent.

417. Nutritive value of dehydrated hay.—Dehydrated alfalfa is used much more commonly than field-cured alfalfa meal as a vitamin A supplement because the carotene content is usually much higher than in good field-cured hay. Dehydrated alfalfa is also generally richer in other vitamins.

In the Vermont experiments dehydrated hay had more than 3 times as much carotene when fed in the winter as did the field-cured hay. In the experiments by the United States Department of Agriculture the difference was even greater between dehydrated hay and field-cured hay. The dehydrated hay when fed had nearly twice as much carotene as did barn-dried hay cured with heated air. On the other hand, wilted alfalfa silage, when fed, had slightly more carotene per pound of dry matter than did the dehydrated hay.

Differing greatly from its high content of carotene, dehydrated hay usually has but little vitamin D, which is formed in field-cured hay by the action of the ultra-violet rays in sunlight. (201) Consequently, dehydrated hay cannot serve as a vitamin D supplement in stock feeding. This fact must be borne in

mind, especially in using dehydrated alfalfa as a vitamin supplement for swine in winter.

In poultry feeding the fact that dehydrated alfalfa has little vitamin D is not important. This is because the kind of vitamin D in field-cured hay has very low efficiency for poultry. (202) Also, the vitamin D requirements of poultry are so high that a special vitamin D supplement is practically always added to the ration, except perhaps for birds outdoors on pasture.

It was found in Vermont experiments that dehydrated hay contained only 4 per cent more total digestible nutrients per 100 lbs. than did field-cured hay made in reasonably good weather from the same crop.[37] The dehydrated hay contained somewhat more total protein than the field-cured hay, because there had been no loss of leaves. However, the protein was less digestible in the dehydrated hay, apparently because of the effect of the heat in dehydration. As a result, the dehydrated hay contained slightly less digestible protein, on the average.

418. Feeding experiments with dehydrated hay.—The use of dehydrated alfalfa or other dehydrated forage as a vitamin supplement for the various classes of stock is discussed in Chapter XVI and in the respective chapters of Part III. Experiments are also summarized there in which dehydrated alfalfa has been used as a protein supplement to replace part or all of the high-protein supplements in rations for dairy cattle, beef cattle, and sheep, or to replace part of the concentrates fed these animals.

As a substitute for good field-cured hay made from the same cutting, dehydrated hay has a slightly higher feeding value per ton. However, the difference in value is usually more than offset by the greater cost of dehydration. Dehydrated hay of course has a much greater value per ton than field-cured hay of poor quality.

Dehydrated hay or pellets made from ground dehydrated hay should not be used to replace all the hay or hay and silage for dairy cows. It is shown in Chapter XXV that this may decrease rumination and considerably lower the fat content of the milk. (1052) In an experiment by the United States Department of Agriculture, when heifers were fed pelleted alfalfa as the sole ration the fat test of the milk was very low.[38]

When used as a supplement to pasture for dairy cows, dehydrated soybean hay produced considerably less milk than when the cows were fed a good concentrate mixture, or grain mixture, to supplement pasture.[39]

419. Dehydrated young forage not a concentrate.—On account of the high nutritive value of young grasses and legumes, experiments have been conducted to determine whether such forage, when dehydrated, could be used satisfactorily as a substitute for grain and other concentrates. Appendix Table I shows that at the pasture stage mixed grass and clover, dried to a hay basis, contains only 19.7 per cent fiber and is very rich in protein. In comparison with this, hay made from crops cut at the usual stage of growth generally has 28 to 30 per cent fiber. The dried immature forage is considerably more digestible than hay and supplies 66.7 lbs. total digestible nutrients per 100 lbs. However, it is lower than most concentrates in total digestible nutrients and especially in net energy.

When dehydrated young grass has been substituted for part of the concentrates usually fed, the production of good dairy cows has been well maintained in some experiments, but it was decreased appreciably in a Washington trial when dehydrated young grass-legume mixture replaced 15 per cent or more of the concentrates usually fed.[40] When the dehydrated grass has replaced all the concentrates for dairy cows and the usual amounts of hay or hay and silage have been fed, the production has been considerably lowered. The ration was then so bulky that the cows could not consume sufficient nutrients to keep up the maximum milk flow.

In a Vermont test cows fed a reduced amount of hay and silage, with

a large allowance of dehydrated grass (greater than the weight of concentrates usually fed), produced as much milk as on a normal ration of concentrates, hay, and silage.[41] The dehydrated grass was also satisfactory as a silage substitute.

On account of the high cost of harvesting the immature grass at frequent intervals and of dehydrating the watery material, the use of such dehydrated grass as a substitute for concentrates does not appear to be practicable under ordinary conditions.

420. Pelleted dehydrated hay.—Some dehydrated alfalfa is pelleted in pelleting machines. Pelleted alfalfa is much less bulky than alfalfa meal and also it can be shipped in bulk. Therefore when the product is shipped a long distance, the cost of shipment may be enough less to more than cover the cost of pelleting. The use of alfalfa pellets for the various classes of stock is discussed in the respective chapters of Part III.

QUESTIONS

1. What characteristics does high-quality hay have?
2. What have experiments shown concerning the relative value of good and poor hay?
3. Discuss the importance of cutting hay early.
4. How high can the water content of hay be for safe storage? How can a farmer tell when hay is dry enough for storage?
5. Discuss the following losses of nutritive value in haymaking, and tell how each can be minimized: (a) Losses by shattering; (b) by fermentation and bleaching; (c) by leaching.
6. What is the approximate total loss of dry matter during field curing in fairly good weather and in storage in the mow for legume hay; for grass hay?
7. Discuss the curing of hay in swath and windrow.
8. Discuss the effects of mowing hay at various times of day.
9. Under what conditions may it be wise to put hay in cocks?
10. What devices are used in curing hay in very rainy districts?
11. Discuss the merits of the hay-loader method of storing hay.
12. Under what condition is the buck-rake method most efficient?
13. Discuss baling hay from the windrow.
14. What danger is there in feeding baled hay?
15. Discuss chopping hay as it is stored.
16. What are the advantages and disadvantages of the barn-drying of hay?
17. What have experiments shown concerning the relative value of barn-dried and field-cured hay?
18. Why is not the making of brown hay advisable?
19. What is the effect of adding salt to hay as it is stored; of using a preservative consisting chiefly of soda?
20. How may losses from spontaneous combustion be prevented?
21. Compare the nutrient losses in dehydrating and field curing hay. Why is not dehydrated hay used extensively for dairy cattle, beef cattle, sheep, or horses?
22. What is the relative carotene and vitamin D content of dehydrated and field-cured hay?
23. Discuss the use of dehydrated hay or young forage as a substitute for concentrates.

REFERENCES

1. U.S.D.A., Handbook of Official Hay and Straw Standards.
2. N.J. Rpt. 1951; Skory and Hartwig, N.Y. (Cornell) Memoir 313.
3. Gordon, Dawson, Moore, and Hosterman, U.S.D.A., Jour. Dairy Sci., 35, 1952, pp. 755–763; see also: Gordon, Moore, and Hosterman, U.S.D.A., Jour. Dairy Sci. 37, 1954, pp. 1116–1122; Kelkar and Gullickson, Minn., Jour. Dairy Sci., 33, 1950, pp. 288–292.
4. Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732.
5. Willard, Ohio Farm and Home Res. 276.
6. Loosli, N.Y. Farm Res., 15, 1949, No. 4.
7. Colovos, Keener, Prescott, and Teeri, N.H., Jour. Dairy Sci., 32, 1949, pp. 659–664; see also: Gullickson, Minn. Farm and Home Sci., 11, 1954, No. 2: Goode, Graham, Lovvorn, and Woodhouse, N.C. Rpt. 1948.
8. Baker, Conrad, Arthaud, and Newell, Nebr. Bul. 403.
9. Dexter, Mich. Quar. Bul. 30, 1947, No. 2.
10. Armsby, Penn. Rpt. 1888; Newlander and Jones, Vt. Bul. 348; Hart, Kline, and Humphrey, Wis., Jour. Agr. Res., 45, 1932, pp. 507–511; Woodman, Bee, and Griffith, Jour. Agr. Sci., England, 20, 1930, pp. 53–62; Watson and Ferguson, Jour. Agr. Sci., England, 21, 1931, pp. 235–246.
11. Shepherd et al., U.S.D.A. Tech. Bul. 1079; see also: Headden, Colo. Bul. 110.
12. Guilbert, Mead, and Jackson, Cal., Hilgardia, 6, 1931, pp. 13–26; Headden, Colo. Bul.

110; Ames and Boltz, Ohio Bimo. Bul. 2, 1917, pp. 178–180; LeClerc, U.S.D.A., Yearbook 1939, p. 997.

13. Shepherd et al., U.S.D.A. Tech. Bul. 1079; Turk, S. H. Morrison, Norton, and Blaser, N.Y. (Cornell) Bul. 874; Camburn, Ellenberger, Jones, and Crooks, Vt. Buls. 494, 509; Newlander, Ellenberger, Camburn, and Jones, Vt. Bul. 459.
14. Archibald, Blaisdell, and Stapleton, Mass. Bul. 449; Huffman, Mich., Jour. Dairy Sci., 22, 1939, pp. 905–911; Elliott, Loosli, and Musgrave, N.Y. Farm Res., 13, 1947, No. 2; Moxon et al., S.D. Rpt. 1947; Hodgson, Knott, Miller, and Murer, Wash. Bul. 366; Hatcher, Ahlgren, and Sund, Wis. Bul. 498; Watson, Silage and Crop Conservation.
15. Diseker, Ala. Rpts. 1932, 1933; Slusher and Fiedler, Ark. Bul. 481; Sitler, Connell, Burdick, and Wheeler, Colo. Bul. 417-a; Henson, Iowa Res. Bul. 251; Dow, Me. Bul. 453; Rather and Moorish, Mich. Quar. Bul., 17, 1935, No. 4; Jones, Leonard, and Hamblin, Miss. Tech. Bul. 27, Miss. Bul. 353; Kiesselbach and Anderson, Nebr. Res. Bul. 36, U.S. D.A., Tech. Bul. 235; Hartwig, Jennings, and Snyder, N.Y. (Cornell) Memoir 310; Stippler and Law, Wash. Bul. 512; Parker and Hosterman, U.S.D.A., Farmers' Bul. 1539; Pollock and Hosterman, U.S.D.A., Farmers' Bul. 1770.
16. Henson, Iowa Res. Bul. 251; Higgins, Mich. Tech. Bul. 83; Jones, Leonard, and Hamblin, Miss. Tech. Bul. 27; Willard, Ohio, Jour. Amer. Soc. Agron., 18, 1926, pp. 369–375; Kiesselbach and Anderson, U.S.D.A., Tech. Bul. 235; Westover, U.S.D.A., Bul. 1424.
17. Ramser and Kleis, Ill. Cir. 693; Einerson, Hauge, and Lundquist, Ind. Rpt. 64; Jones and Dudley, Miss. Cir. 137; Turk, S. H. Morrison, Norton, and Blaser, N.Y. (Cornell) Bul. 874; Buchanan, N.D. Bul. 371; Knodt, Penn. Bul. 502; Ahlgren, Duffee, and Hatcher, Wis. Bul. 487; Wyo. Roundup, 2, 1954, No. 2.
18. Markeson, Id. Cir. 120; Hardin, Ind., Country Gentleman, July, 1952; Vary, Mich. Spec. Bul. 392; Skinner, Mont. Bul. 203; Lamborn, N.Y. (Cornell) Bul. 855; Fife and Ames, N.Y. Farm Res., 20, 1954, No. 2; Keeper and Adkinson, Penn. Bul. 490; Hodges, Wis., Hoard's Dairyman, Apr. 10, 1952; Marx and Birkhead, U.S.D.A. Cir. 868.
19. Davidson, Barger, and Shedd, Iowa Rpt. 1943, Part 1; Ahlgren and Bender, N.J. Cir. 440; Harrison, Savage, and Hartwig, N.Y. (Cornell) Exten. Bul. 461, Schroeder and Ackerman, Penn., Science for the Farmer, June, 1944; Schroeder and Ackerman, Penn., Agr. Engin., 26, 1945, pp. 27–28; Burcalow and Bruhn, Wis. Bul. 463.
20. Schoenleber and Shepherd, U.S.D.A., mimeo. rpt.
21. Turk, S. H. Morrison, Norton, and Blaser, N.Y. (Cornell) Bul. 874.
22. Shepherd et al., U.S.D.A. Tech. Bul. 1079.
23. King, Wilbur, Hauge, and Cooper, Ind., Jour. Dairy Sci., 33, 1950, pp. 16–23; Archibald, Blaisdell, Cox, and Stapleton, Mass. Bul. 464; Little and Wolcott, Mich. Quar. Bul., 35, 1952, No. 1; Reaves, Rollins, Eheart, and Linkous, Va. Bul. 431; see also: Carter, Vt. Bul. 566; Camburn, Vt., Jour. Dairy Sci., 31, 1948, p. 691.
24. Lutz and Wolcott, Mich. Quar. Bul., 32, 1949, No. 2.
25. Dickey, Plummer, and Banton, Maine Buls. 483, 519; Perkins, Krauss, and Skinner, Ohio Bul. 665; Hinton, Miles, and Wylie, Tenn. Rpt. 1947; Tenn. Rpt. 1950; Newlander, Jones, and Foote, Vt. Bul. 561; see also: Colovos, Keener, Teeri, and Davis, N.H. Bul. 409.
26. Dickey, Moran, Plummer, and Getchell, Maine Bul. 473.
27. Dowe and Arthaud, Nebr. Rpt. 63.
28. Caine, Iowa Rpt. 1946, Part 1.
29. Weihing, Robertson, Coleman, and Gardner, Colo. Bul. 480; Swanson, Call, and Salmon, Kan., Jour. Agr. Res., 18, 1919, pp. 299–304; Bechtel, Shaw, and Atkeson, Kan., Jour. Dairy Sci., 28, 1945, pp. 35–48; Honcamp, Germany, Landw. Vers. Sta., 100, 1922, pp. 79–88.
30. McCampbell, Kan., Jour. Agr. Res., 18, 1919, pp. 303–304; Cox and Sloan, Kan. Rpt. 1944–46; Cave and Fitch, Kan. Rpts. 1926–28, 1928–30; Maynard, Esplin and Boswell, Utah Bul. 238.
31. Tysdal and Kiesselbach, Nebr. Bul. 331; Hartwig, N.Y., Hoard's Dairyman, 75, 1930, p. 667; Roethe, U.S.D.A., Agr. Engin., 18, 1937, pp. 547–550, 554; Hoffman and Bradshaw, U.S.D.A., Jour. Agr. Res., 54, 1937, pp. 159–184; Pollock and Hosterman, U.S.D.A. Misc. Pub. 363; Shutt, Canada Expt. Farms, Div. Chem., Rpt. 1927; Phillips, Davies, and Ashton, Jour. Min. Agr., Great Britain, 52, 1945, pp. 98–99; Robinson and Burns, Jour. Min. Agr., Great Britain, 52, 1945, pp. 100–101.
32. Ind. Rpt. 1951; Kleis and Wiant, Mich. Quar. Bul. 36, 1953, No. 1; Musgrave and Dawson, N.Y. Farm Res., 12, 1946, No. 2; Kennedy and Schenk, N.Y. Farm Res., 19, 1953, No. 2; Patterson and Law, Wash. Cir. 135.
33. Browne, U.S.D.A. Tech. Bul. 141; U.S.D.A., Rpt. of Conference on Spontaneous Heating and Ignition of Agricultural and Industrial Wastes, 1930; Roethe, U.S.D.A., Agr. Engin., 18, 1937, pp. 547–550, 554; Hoffman, U.S.D.A., Jour. Agr. Res., 61, 1940, pp. 241–257; Reed, Ind. Cir. 229; Lamb, Iowa Cir. 36; James and Price, Science, 67, 1928, pp. 322–324.
34. Hosterman, U.S.D.A. Leaflet 72; U.S.D.A. Tech. Bul. 239.
35. Johnson, Id. Cir. 78.
36. Schneider and VanLandingham, West Va. Bul. 332.
37. Camburn, Ellenberger, Jones, and Crooks, Vt. Buls. 494, 509; see also: Murdoch, Miller, Blosser, and Erb, Wash., mimeo. rpt.
38. Rpt. of Chief of Bur. Dairy Industry, U.S.D.A., 1950–51.
39. Snell, La. Rpt. 1929–31.
40. Newlander, Vt. Buls. 348, 350; Knott and Hodgson, Wash., Jour. Dairy Sci., 17, 1934, pp. 409–415; Watson and Ferguson, Jour. Agr. Sci., England, 26, 1936, pp. 189–211; see also: Hope et al., Wash., Jour. Dairy Sci., 133, 1950, pp. 306–314.
41. Camburn, Vt. Buls. 359, 369.

CHAPTER XV

SILAGE AND CROPS FOR SILAGE

I. The Ensiling of Forage Crops

421. Advantages of silage.—In most of the leading stock-farming districts of the United States silage is a feed of great importance. This wide use of silage is the result of the following advantages:

1. The use of silage generally makes it possible to keep more stock on a certain area of land.

Over most of this country either corn or the sorghums surpass other forage crops in yield of total digestible nutrients per acre. They may readily be made into excellent silage, and a far greater feeding value is secured when these crops are used for silage than when they are fed as dry fodder or when the grain is removed and the grain and stover are fed separately.

During recent years the making of hay-crop silage, or "grass silage" has increased greatly in this country. It has been shown in the previous chapter that the losses of nutrients are less when a hay crop is made into silage by a good method than when it is made into field-cured hay. (398) The difference is especially great in the case of carotene.

2. At a low expense silage furnishes high-quality succulent feed for any season of the year. In winter, silage is far cheaper than roots, and in summer it is much more economical than a succession of specially grown soiling crops.

3. Crops may be ensiled when the weather does not permit curing them into hay or dry fodder.

4. Silage, even from plants with coarse stalks, such as corn and the sorghums, is eaten practically without waste. On the other hand, a considerable part of dry corn or sorghum fodder is usually wasted, even if it is of good quality.

5. Weedy crops, which would make poor hay, may produce satisfactory silage, and the ensiling process kills many kinds of weed seeds.

6. The crop from a given area can be stored in less space as silage than as dry forage.

7. When a corn or sorghum crop is ensiled, the forage is removed from the land early, so that it may be prepared for another crop.

8. In areas where there is considerable damage from the European corn borer, cutting the stalks close to the ground and then ensiling the crop is one of the best methods of controlling the pest.

The importance of silage in this country is shown by the fact that over 6,000,000 acres of corn and 1,000,000 acres of sorghums are grown annually for silage. In addition, considerable acreages of hay crops are ensiled, data for which are not available.

422. Value and use of silage.—Because of the importance of silage, its value and use for the various classes of stock are discussed in detail in the chapters of Part III. Information is also given in the following chapters about the most important silage crops.

Apart from the nutrients it contains, good silage has certain merits not possessed by most dry roughages. It is highly palatable, and therefore stock will usually eat more roughage on the dry basis, when fed silage in addition to hay or other dry forage, than when receiving only dry feed. This often makes possible a considerable saving in the amount of concentrates required for good production.

Silage is slightly laxative. This is especially beneficial when little or no legume hay is fed. If cattle or sheep have only dry non-legume roughage dur-

ing the winter they are apt to become constipated and unthrifty.

Stock are not injured by the considerable amounts of silage acids that they consume when they are fed silage continuously for a long time. The organic acids in silage are similar to those normally produced in the digestive tract of ruminants in the digestion of the fiber and pentosans of the feeds through bacterial action. These acids are used by the animal for food in the same manner as are the sugars. (As mentioned later, the mineral acids used in making phosphoric acid or A.I.V. silage should be neutralized by feeding ground limestone or a similar substance.)

SAVING ALL OF THE CORN CROP BY ENSILING IT

When the corn crop is ensiled at the proper stage of maturity, the full value of both grain and stover is secured for dairy cattle, beef cattle, and sheep.

Silage is used most extensively for the feeding of dairy cattle, especially dairy cows. Cows will generally produce more milk on a ration containing both silage and good hay than when only dry roughage is fed. The only exception is when they have an abundance of excellent legume or mixed legume-grass hay of considerably better quality than the average. Silage is particularly important for milk production when the available dry roughage is rather inferior. To avoid injury to the flavor of milk, silage should be fed after milking, and it should not be left in the stable.

Silage is just as useful and economical for beef cattle and sheep as it is for dairy cows. In fact, as is pointed out in Chapter XVII, the value per ton of well-matured corn silage for fattening cattle or lambs is even slightly higher, in comparison with that of hay, than it is for dairy cows. Silage aids in keeping beef breeding cows and breeding ewes in thrifty condition during the winter, as well as being a cheap feed for them.

Good silage may also be used in a limited way with idle horses and those not worked hard in winter, especially brood mares and colts. Silage is used but little for swine or poultry. Well-cured legume hay, particularly alfalfa hay, is better as a vitamin supplement for them.

Only as much silage should be supplied as will be cleaned up at each feed-

ing. Care should be taken to remove any waste, for it spoils in a short time on exposure to the air. Frozen silage must be thawed before feeding. Spoiled, moldy silage should be discarded, and one should be especially careful not to feed such silage to horses or sheep, because they are much more apt to be injured by it than are cattle. Silage which is unusually sour may cause digestive disturbances with sheep.

The amounts of silage commonly fed per head daily to the various classes of stock are about as follows:

Dairy cows, 30 to 50 lbs. for those in milk, with somewhat less for dry cows; dairy heifers, 12 to 20 lbs.; beef breeding cows, 30 to 50 lbs.; fattening 2-year-old steers, 25 to 30 lbs. at the beginning of the fattening period, the allowance decreasing as they fatten until only 10 to 15 lbs. are fed; fattening calves, from 10 to 20 lbs. at the beginning of the feeding period to 8 to 10 lbs. or less during the latter part; brood mares and idle horses, 15 to 30 lbs.; breeding ewes, 2 lbs. per 100 lbs. live weight (sometimes more is safely fed); fattening lambs, 1.5 to 3.0 lbs.

423. Silage for summer feeding.—Many farmers who fully appreciate the value of silage for winter feeding do not realize its value for supplementing dried-up pastures in the summer. It is also economical as a partial substitute for pasturage on high-priced land where all the stock possible must be kept per acre. Silage is generally much cheaper and more satisfactory than growing a succession of green soiling crops for these purposes. (**386–387**)

Silage can be used for summer feeding only if enough animals are fed to use 2 inches or more of silage daily from the entire surface of the silo, so as to prevent spoilage.

424. Economy of silage.—Numerous experiments have proved that silage is more economical and efficient than dry corn or sorghum fodder for dairy cattle, beef cattle, and sheep. There is, however, some difference of opinion as to whether silage is actually a cheaper feed than good hay.

The table in the following chapter shows that in the United States corn silage furnishes twice as much total digestible nutrients per acre as does clover-and-timothy hay, and 31 per cent more than does alfalfa hay. (**450**) These facts are of great importance to the farmer who desires to produce as much feed as possible on his farm.

In cost-accounting studies in the corn belt states, the cost per ton of corn silage, including ensiling the crop, has usually been about 30 to 40 per cent of the cost per ton of producing alfalfa hay or mixed hay. Under such conditions there is no question but what corn silage is a very economical feed, in comparison with hay. Numerous experiments have shown that corn silage is worth 33 to 40 per cent as much a ton as good hay for dairy cows and fully one-half as much as such hay for fattening beef cattle and sheep.

Even where the cost of silage, as found in cost-accounting studies, is fully one-half as much per ton as that of good hay, silage may still be an economical feed. This is because other factors must be considered than merely the cost per ton as found in such investigations.

First, all labor is valued at a uniform price per hour in such studies, regardless of whether it is in a rush season or not. When both corn silage and hay are produced, the demand for labor is distributed much better than when only hay is used for winter roughage. Therefore, the need of extra hired labor during hay-making may often be avoided.

The growing of a cultivated crop, such as corn or sorghum for silage, may have a special value in the crop rotation for the control of weeds.

In humid regions a considerable part of the hay crop will often be injured by rain, in spite of good management. It cannot be assumed therefore that the average hay actually fed on stock farms is of a high market grade. Much of it is, in fact, decidedly inferior. On the other hand, corn or sorghum silage is generally of high quality, if even moderate care is taken in ensiling the crop.

Last, but not least, it is often difficult in humid districts to cure, without

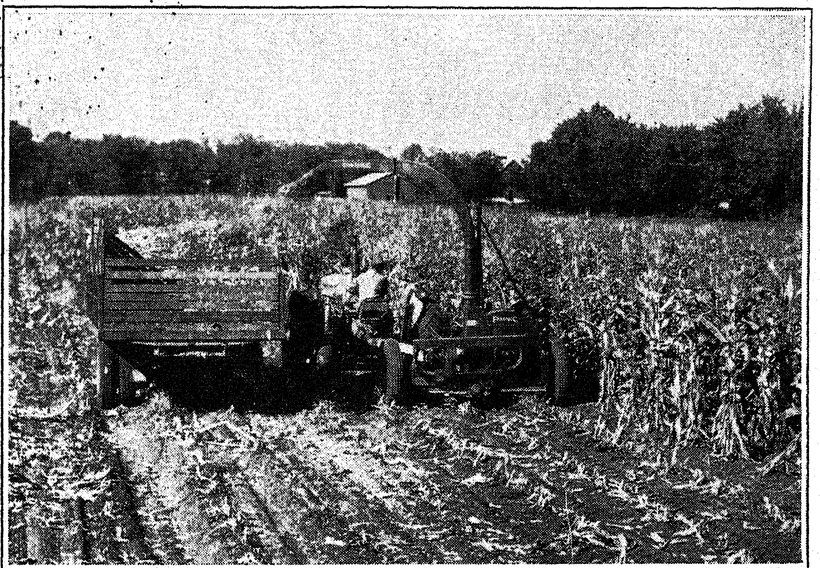
serious damage from rain, a large acreage of hay before it becomes too mature. This difficulty is much greater when hay is the only roughage than if silage is also produced.

Considering all of these factors, we can conclude that silage is an economical feed for cattle and sheep over most of the United States. However, in the irrigated districts of the West there are many areas in which the cost of producing high-quality alfalfa hay is very low in comparison with the cost of silage. Here hay may be a decidedly more economical feed.

The cost per ton of silage will obviously depend largely on the yield per acre. Corn or sorghum for silage should therefore be grown on land well adapted to the crop, and the field should be so fertilized and tilled that it will produce a large yield per acre.

The cost of ensiling the crop should be reduced as much as possible by using efficient methods. Where a corn binder is used for harvesting the crop, a bundle elevator and low-rack wagons save much labor. In ensiling the crop, time can be saved by keeping the cutter knives sharp and properly adjusted, and by running the cutter at the proper speed.

Where the acreage of silage and hay crops is large enough to warrant the expense for the equipment, the field chopper method of harvesting is most economical. (407)



HARVESTING CORN FOR SILAGE WITH A FORAGE HARVESTER

The expense of the equipment is distributed, when a forage harvester is used both for harvesting corn for silage and also for chopping hay from the windrow or for hay-crop silage.

425. How ensiling preserves green forage.—When green forage from a suitable crop is placed in a compact mass in a silo the following changes take place which convert it into silage: [1] For a time the living plant cells continue to respire, or breathe, rapidly using up the oxygen in the air entrapped in the mass and giving off carbon dioxide (carbonic acid gas). Within 5 hours practically all the oxygen has disappeared, and this prevents the development of molds, which are unable to grow in the absence of oxygen.

Acid-forming bacteria multiply enormously in the silage, and at the end of 2 days each gram of silage juice (about

one-fourth of a teaspoonful) may contain many billions of bacteria. These bacteria attack the sugars in the green forage, producing organic acids, chiefly lactic acid (the acid of sour milk), with some acetic acid (the acid of vinegar), and traces of other acids and also of alcohol. The production of acid is the most important change in the process, for acidity prevents the growth of undesirable bacteria, such as cause rotting, or putrefaction.

When enough acid has been formed, the fermentation is checked, and finally the action practically ceases. If air does not gain entrance, the silage will then keep for long periods with but little change. Instances are on record where corn silage 12 years or more old has been of satisfactory quality. If air does penetrate, as at the top of the silo or adjacent to a crack in the wall, mold will grow and destroy the acid. Putrefactive bacteria can then develop and cause further spoilage.

Corn or sorghum forage makes the best silage when the dry matter content is not less than about 27 or 28 per cent. To make good-quality silage from hay crops, such as alfalfa or grass, without a preservative the dry matter content should be 30 to 35 per cent. If the forage has less dry matter, there will be considerable loss of juice, and the silage is apt to be of poor quality unless a preservative is added, as described later.

If the percentage of water in the silage is too high, an undesirable type of fermentation is apt to occur, in which strong-smelling butyric acid is formed, instead of the much more palatable lactic and acetic acids. If the forage is too dry, it is apt to mold.

While the sugars are the chief compounds acted upon by the bacteria in the acid fermentations, the starch and pentosans may be attacked to a limited extent. However, the amount of acid developed in the silage depends largely on the percentage of sugar in the ensiled crop. If the forage is very high in sugar, as in the case of very immature corn or sorghum, so much acid may develop that the silage will be unpalatable to stock. Also, the feeding value will be lowered, because there will be a greater loss of nutrients in the fermentations. Normally the amount of acid in good corn silage is not greater than 1.0 to 2.4 per cent of the total weight.

In addition to the acids, some ordinary or ethyl alcohol is produced and also traces of other alcohols. The alcohols largely combine with the acids to form compounds that aid in producing the characteristic aroma of good silage. Yeast cells develop in the silage to some extent in the early stages of the process, but are relatively unimportant.

In silage formation the proteins in the green forage are broken down or digested to a considerable extent, probably by the enzymes in the plant cells. Such changes are similar to those that occur when proteins are digested into simpler compounds in the animal body, and therefore the action is not detrimental. However, in poorly preserved silage made from protein-rich hay crops, further break-down of protein may occur, resulting in considerable loss.

During the fermentations in silage, the temperature rises somewhat, but if the mass is well compacted, so that very little air is present, the temperature in the interior of the silo rarely exceeds 100° F. The changes are therefore far less extensive than those which take place in the making of brown hay. (412)

Very rarely, many spots of rotten silage occur in the midst of good silage. Such spoilage can be produced by certain bacteria which are not checked by the acidity or the lack of oxygen, but instead destroy the acid and rot the silage.[2] Where there has been this trouble, it is recommended that the silo walls be cleaned and painted with hot tar before filling, in order to kill the bacteria.

426. Efficiency with which silage preserves nutrients.—If a forage crop is ensiled in a large, well-made silo, the losses of dry matter and digestible nutrients are slightly less than when the crop is made into hay or dry fodder, even if the weather is satisfactory for field curing.[3] This is true for corn or sorghum forage and also for hay crops,

such as alfalfa or grasses. In poor weather for field curing, the losses will be much greater in hay or dry fodder than in silage. The carotene content of the green crop is generally preserved much better in silage than in hay or dry fodder.

The chief loss of nutrients in silage is through the oxidations that take place in the normal fermentations and other changes which occur in the silage process. In these changes a part of the nutrients (chiefly the sugars) is oxidized to carbon dioxide and water and thus lost. This loss should not amount to more than 5 to 10 per cent of the dry matter of the crop, if it is ensiled in a deep, well-built, cylindrical silo by a good method. When the mass of forage is not well compacted, as in a shallow silo, this loss may be much greater.

In addition, there is a loss through the spoilage of silage at the top of the silo, unless feeding begins as soon as the filling is completed. In a shallow silo, the percentage loss through this top spoilage is much greater than in a deep silo, because the forage that spoils at the top represents a greater proportion of the entire weight.

In a silo that is at least 30 feet deep, the top spoilage should not exceed more than 4 to 6 per cent of the dry matter. The top spoilage can be kept to a minimum by one of the methods of covering the surface which are mentioned later. (444)

If the forage is too high in water content when it is ensiled, a third loss will occur in the juice that runs out. The loss by this means should not exceed 1 to 3 per cent of the dry matter in the case of corn or sorghum forage that has reached the proper stage of maturity, or in the case of a hay-crop that has been slightly wilted before it is ensiled.[4]

The loss by seepage will be considerably higher if the forage is too watery. When the excess juice cannot escape from silage that is high in water, the silage will often be very sour and less palatable than that from crops lower in water.

In silos at least 30 feet deep, the total loss of dry matter should not exceed 10 to 15 per cent in corn or sorghum silage, if reasonable care is taken to reduce the surface spoilage and if there is little or no loss of juice. This loss is appreciably lower than the loss of dry matter that usually occurs when corn or sorghum forage is cured as dry fodder, or when a legume hay crop is made into hay by ordinary methods. (To determine the dry matter content of silage accurately, it is necessary to correct for the loss in ordinary drying of volatile nutrients, such as some of the organic acids.[5] Often this has not been done, and losses of dry matter have been reported which are too large.)

Even when cured in well-made shocks, corn fodder or stover standing in the field for a few months loses at least 15 per cent and usually 20 per cent or more of the dry matter it contains, because of weathering and fermentations which gradually waste the forage.[6] With unfavorable conditions the wastage is much greater. The losses are chiefly in the most valuable parts of the plant—the protein, sugar, and starch—which are less resistant and more soluble than the fiber.

The loss of dry matter in hay-crop silage is usually somewhat greater than in corn or sorghum silage. However, it should not be more than 20 to 25 per cent, if a good method is used and undue loss by seepage is avoided.

It has been shown in the previous chapter that in fairly satisfactory hay-making weather the loss of dry matter in making and storing legume hay by good field-curing methods may total 20 to 30 per cent. (398) In rainy weather the loss will be considerably greater.

427. Crops for the silo.—To make silage, a green forage crop must have certain qualities. First, it must be neither too dry nor too high in water content. If it is too dry, it will not pack well in the silo, and enough air will remain to permit the development of mold. If the forage is too high in water, the silage is apt to be very sour or it may even spoil.

It is essential that there be enough acid in the silage to prevent the growth

of undesirable bacteria that cause rotting or putrefaction. The forage must therefore contain a sufficient amount of sugar, or else one of the special methods must be used which are described later.

To make the best silage, the forage crop should have solid stems, so that only a small amount of air will remain in the mass after it has settled. In the case of the hollow-stemmed small grains, the cut forage must be tramped with especial care to force out as much air as possible.

made from a true grass, such as timothy; from a legume, such as alfalfa; from a mixture of legumes and grasses; or from a green cereal, such as oats. The author prefers the term hay-crop silage, as it is more exact and correct.

The special methods used in making hay-crop silage are described in the following articles. Various other kinds of silage are discussed in the later chapters, including silage made from pea vines from canning factories, sweet-corn cannery waste, green sweet corn stover, soft

A BUNDLE ELEVATOR SAVES LABOR

A bundle elevator on the corn harvester saves much hard labor in loading the heavy bundles. (From New York State College of Agriculture, Cornell University.)

The suitability of various crops for silage is discussed in the following chapters. Corn and the sorghums are ideal silage crops. At the proper silage stage they contain enough sugar so that sufficient acid is produced in the silage fermentations to make silage of high quality. With these crops there is no need whatsoever of adding a preservative, such as molasses or mineral acid.

Especially in the northeastern states, the making of "grass silage," or hay-crop silage, has increased greatly in recent years. Grass silage is the term applied popularly to silage made from any uncured hay crop, no matter whether it is

or immature ear corn, sunflowers, beet tops, wet beet pulp, apple pomace, and potatoes.

Weeds and other waste vegetation may sometimes be advantageously ensiled. Cabbage, rape, and turnips make unsatisfactory silage, ill-smelling and watery.

428. Special methods necessary to insure good hay-crop silage.—Unless a special method is used in ensiling a hay crop, particularly a legume crop, the silage is apt to be of poor quality. On the other hand, very satisfactory silage can be made by the methods described later.

The chief reason why a special method is necessary in ensiling hay crops is that they contain a much smaller percentage of sugars than does corn or sorghum forage at the proper silage stage.[7] Sufficient acid may therefore not be produced in the silage to keep it from spoiling or from having a very strong, undesirable odor.

Legume forage, such as alfalfa or clover, is lower than grass forage in sugars. Also, legume forage is more alkaline in nature than corn or sorghum forage, and this alkalinity neutralizes some of the acid that is formed through the fermentation of what sugar there is in the crop.[8] In addition, legume forage tends to bind chemically and counteract acidity, because of its richness in protein.

Another reason why a special method is needed to make good hay-crop silage is that green legumes and grasses at the usual hay stages generally have less than 25 per cent of dry matter. Such forage is too watery to make high-quality silage unless a special method is used. Alfalfa or clover in early bloom or before bloom may have only 20 to 23 per cent dry matter or even less.

Many investigations have been conducted in recent years by experiment stations in this country to determine the best methods to use in making silage from hay crops. The most important results of these studies are summarized in the following articles.

429. Wilting the forage.—It has previously been pointed out that to make high-quality silage, hay crops should contain 30 to 35 per cent dry matter. If possible, the crop should therefore be allowed to wilt somewhat in the swath before it is ensiled, in order to bring the dry matter percentage up to this level. Wilting is impossible when a forage harvester is used which chops the forage as it is mowed. On a dry, sunny day an interval of 2 to 3 hours between mowing and loading will probably be enough for sufficient wilting. If the forage dries out too much, it will not pack well and it is apt to mold. Also, more of the carotene (vitamin A value) will be destroyed. In a very dry season, or with rather mature crops, wilting of the forage is not necessary.

One reason why wilting the forage improves "grass silage" is that it increases the amount of sugar in each pound of forage, due to the removal of part of the water. Pennsylvania studies also indicate that wilting such forage as alfalfa actually increases the percentage of sugar in the forage, on the dry basis.[9] If legumes or grasses are wilted to just the right extent, silage of good quality can usually be made from them without the addition of any preservative. However, it is difficult to get exactly the right amount of dry matter in the forage, and therefore many farmers prefer to use a preservative, even when the crop is wilted before it is ensiled.

If watery forage crops are not wilted, there is apt to be much leakage of juice from the silo, if the excess juice can get out. This not only wastes nutrients, but the juice is apt to be very foul-smelling as it decays. In addition, watery silage exerts such great pressure on the silo that the walls may give way. Such silage also has a destructive action on concrete.

Many farmers use the "squeeze test" to determine whether the forage has the proper dry matter content. A handful of the chopped forage is given a good hand squeeze with both hands. If moisture appears between the fingers, or if the material stays in a compact ball when pressure is released, it is too wet to ensile without a preservative.

If it expands gradually, the dry matter content is probably about right. On the other hand, if it crumbles and falls apart, it is too dry. The test does not work well with forage containing a high percentage of Ladino clover or with very coarse forage, such as sweet clover.

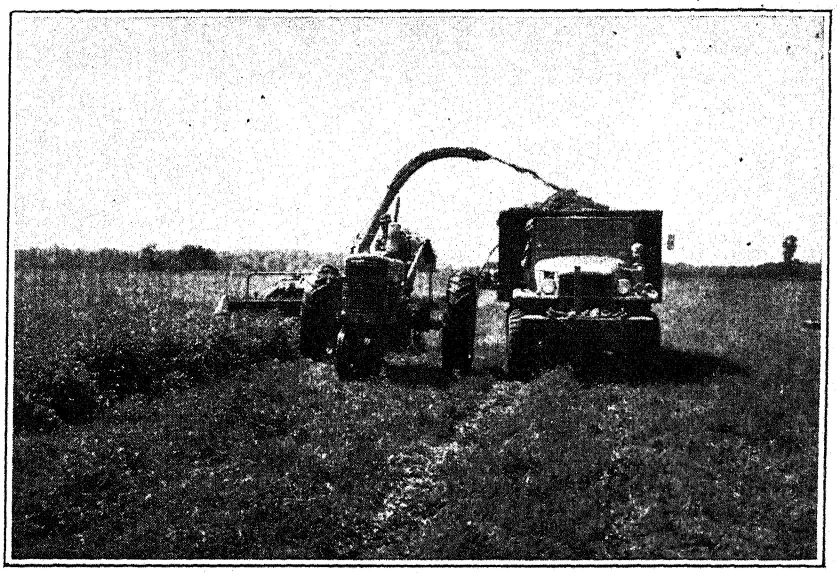
The moisture content of the forage can be determined by cutting up with shears a carefully taken sample and weighing it before and after drying in an oven at a low heat.[10] A home-made moisture tester for silage has been devised and also other relatively simple moisture testers.[11]

430. Addition of molasses.—The method used most widely in this country for improving hay-crop silage, or so-called "grass silage," is the addition of molasses as a preservative. This increases the sugar content so that enough acid is formed in the fermentations to preserve the silage properly.

The addition of molasses decidedly improves the quality of legume or grass silage that is too low in dry matter to make good silage otherwise. Even when the forage is wilted, molasses is apt to improve the quality and palatability of the silage, unless the dry matter content is just right and due care is taken in ensiling the forage. The carotene content of the silage also tends to be higher when molasses is added.

Most of the feeding value of the molasses that is added remains in the silage, because the sugar in the molasses is converted chiefly into lactic and acetic acids, which have food value. It is estimated that about 75 per cent of the nutritive value of the molasses remains in the silage. Cane molasses, beet molasses, corn molasses, citrus molasses, or wood sugar molasses can all be used for this purpose.

The amount of molasses needed per ton of green forage will range from 80 lbs. (7 gallons) for legumes in early bloom or before, to 40 lbs. for grasses or green cereals. The more immature the crop is, the larger is the amount of molasses advised. Some recommend 100 lbs. of molasses per ton for soybeans ensiled before the seed has developed much.



CUTTING A LEGUME-GRASS MIXTURE FOR SILAGE

The making of hay-crop silage, or so-called "grass silage," has increased greatly in recent years. This fine crop of mixed legumes and grass should make good silage. (From New York State College of Agriculture.)

If the silage cutter or blower is not equipped with a molasses pump, the molasses can be run into the blower or the silage cutter from a barrel on an elevated platform, through a hose or pipe with a valve for adjusting the rate of flow. In cool weather if the molasses is too thick to flow fast enough, it can be diluted with a little water.

431. Addition of ground grain or other dry feeds.—Experiments have shown that excellent silage can be made

from legumes or other hay crops when there is added as a preservative ground grain or certain other dry concentrates. One of the benefits from such an addition to forage low in dry matter is that it decidedly increases the percentage of dry matter.

For example, 150 lbs. of grain (about the usual amount added per ton of forage) contains over one-quarter as much dry matter as there is in a ton of green hay crop with 22 per cent dry matter. Adding the grain will raise the dry matter in the silage to more than 26 per cent.

The addition of ground grain also increases the palatability of the silage, because grain is so well liked by stock. Adding grain may also increase the amount of acid produced in the silage, as some acid may be formed from the starch in the grain. Probably at least 75 per cent of the feeding value of the grain is retained in the silage.

The following amounts of ground grain should be added per ton of green forage: For alfalfa, clovers, or lespedeza, 125 to 150 lbs.; for soybeans, 200 lbs.; for grass or cereal forage, 75 lbs.; and for mixed legumes and grasses, 100 to 125 lbs., depending on the proportion of legumes. If corn-and-cob meal is used instead of ground corn or other grain, the amount should be increased about one-quarter.

Good results have been secured when there has been added in making hay-crop silage similar amounts of dried citrus pulp, dried beet pulp, dried molasses-beet pulp, or brewers' dried grains.

Sometimes 300 to 400 lbs. of dry corn or sorghum fodder or stover, or else hay, are added to each ton of a watery hay crop as it is run through the silage cutter. Experiments have shown that it is doubtful whether this usually produces as good silage as is made when the hay crop is merely wilted to the proper degree.

432. Addition of mineral acid.—Another method is the addition of acid to the forage as it is ensiled. This acid, together with the acid formed through the fermentation of the sugar contained in the crop, produces sufficient acidity to make satisfactory silage. This method has been used but little by farmers in this country.

Sometimes phosphoric acid has been used as a preservative in making hay-crop silage. It does not have the strong corrosive effect of such acids as sulfuric acid or hydrochloric acid. Also, it increases the residual manurial value of the silage. Food-grade phosphoric acid should be used, as lower grades may contain injurious substances. The amount of liquid phosphoric acid generally recommended per ton of forage ranges from 16 lbs. (5 quarts) of 68-per-cent phosphoric acid (or 14 lbs. of 75-per-cent acid) for legumes to 9 lbs. of 68-per-cent phosphoric acid for grasses or cereals. About one-half of the cost of the phosphoric acid is returned in the increased fertility value of the manure resulting from feeding the silage.

The nutrients in a hay crop are well preserved by the phosphoric-acid method. However, in recent experiments the silage has been somewhat less palatable to stock than silage made with molasses or ground grain as the preservative. Also, when dairy cows have been fed large amounts of phosphoric-acid silage for a long period, they sometimes have not seemed to be as thrifty as when fed other silage.

In order to neutralize the considerable amount of mineral acid in phosphoric-acid silage, ground limestone or some other form of calcium carbonate should be fed with it.[12] For cattle, 2 ounces per head daily of ground limestone or a mixture of limestone and sodium bicarbonate are sufficient.

In the A.I.V. method, a mixture of hydrochloric acid and sulfuric acid is added to the forage. This patented method is employed to a considerable extent in northern Europe, where hay-crop silage is commonly made in pits or trenches, often without chopping. It has been used but little in the United States, because it has no special advantages, and the acids have a destructive action on clothing, the silo-filling machinery, and the silo wall.

433. Ensiling mixtures of legumes and other forage.—Good silage can be made from a mixture of legume forage, such as alfalfa or soybeans, with a suitable proportion of green corn or sorghum forage, which contains much more sugar. Since sorghum forage has more sugar than corn forage, less of it is needed. One ton of green sorghum to each 3 tons of alfalfa or soybeans should be sufficient, while it is best to have about equal weights of corn forage and legume forage.

434. Sodium bisulfite; sulfur dioxide.—A few years ago the use of sulfur dioxide was proposed to improve the quality of hay-crop silage, by decreasing the fermentations. At first, the method was used of injecting sulfur dioxide gas into the ensiled forage, from the cylinders in which it is shipped under great pressure, at points a few feet apart into each 2 or 3 foot layer of silage.[13] This method takes considerable time and the sulfur dioxide may not become uniformly distributed in the forage.

A much less troublesome way of adding sulfur dioxide is to add 8 lbs. of sodium bisulfite per ton to the forage as it is ensiled.[14] Sodium bisulfite (sodium metabisulfite) has been used for many years in the preservation of certain human foods.

The sodium bisulfite, which is a dry powder, can be applied to the chopped forage as it is ensiled by means of a special device, or by means of a fertilizer distributor, borrowed from a corn planter.

Several experiments have been conducted to compare this method, proposed by the Pennsylvania Station in 1952, with other methods of making hay-crop silage.[15] These studies have shown that the chief advantage of the method is that it usually improves the odor of the silage decidedly, due to a reduction in butyric acid and in putrefaction. Also, the addition of sodium bisulfite may increase the preservation of carotene, but all good hay-crop silage has an abundance to meet the needs of livestock.

In some experiments sodium bisulfite silage has been more palatable than other hay-crop silages, but in other trials it has been less palatable even than silage made with no preservative. While the results of the various experiments have differed considerably, the sodium bisulfite method does not apparently reduce the loss of dry matter appreciably, or improve the digestibility of the silage.

The most extensive feeding trials with sodium bisulfite silage yet reported are those by the New York (Cornell) Station.[16] During 2 seasons silage was made from mixed legumes and grasses (75 per cent legumes), cut when the legumes were in early bloom. The forage contained only about 20 per cent dry matter and was not wilted, as it was harvested with a field chopper. Each kind of silage tested was fed as the only roughage to dairy cows, with the usual amount of concentrate mixture.

In amount of silage eaten per head daily, in milk production per cow, in dry matter required per pound of milk, and in gain in live weight, the sodium bisulfite silage ranked slightly below silage made with no preservative or silage made with molasses. In warm weather the sodium bisulfite silage tended to spoil, after removal from the silo, sooner than the other silages. The only advantage of adding sodium bisulfite seemed to be the production of good-smelling silage, and a somewhat better preservation of carotene. However, the other silages had plenty of carotene.

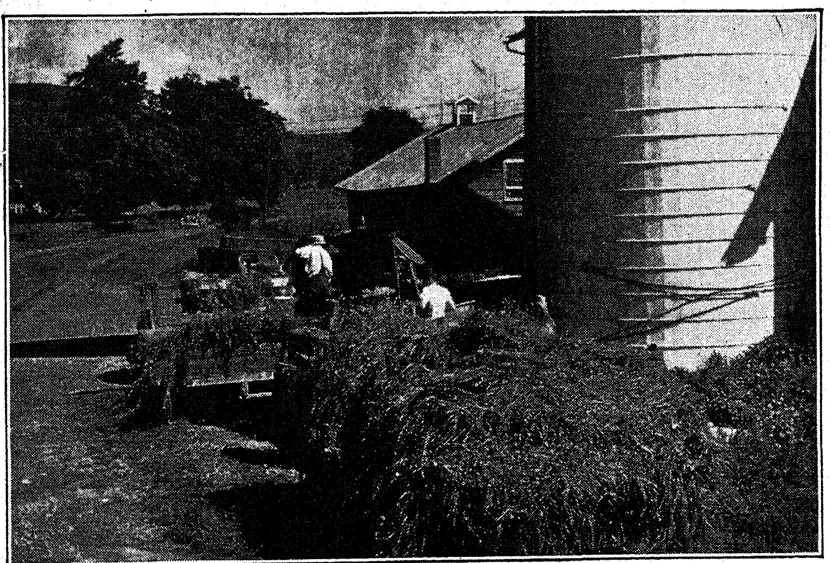
435. Other methods.—Sometimes dried whey or even undried whey is added in ensiling a hay crop. The results are apt to be inferior to those from using molasses, ground grain, or mineral acid, or from wilting the crop.

Silage made with the addition of a commercial mixture consisting chiefly of calcium formate and sodium nitrite was inferior to no preservative or sodium bisulfite silage in an Illinois trial, and to silage made from wilted forage in an experiment by the United States Department of Agriculture.[17]

Occasionally salt is added to the hay-crop forage, but it is very doubtful whether this produces any appreciable benefit.

Claims that lactic acid cultures improve the quality of silage have been proven false.[18] All green silage crops have an abundance of such bacteria. Methods of treating the ensiled forage with currents of electricity[19] or steaming it[20] to kill the bacteria have not proven advantageous.

In an Italian method grasses or legumes are dried to a dry matter content of 60 to 70 per cent before ensiling.[21] The silage is heavily weighted in a tower silo by means of a wooden cover and large stones, so as to force out most of the air and reduce the fermentations. Without such weighting, forage as dry as this would be apt to mold or even char.



MAKING A HAY CROP INTO SILAGE CONSERVES NUTRIENTS

The loss of nutrients is usually less when a hay crop is made into silage by a suitable method than when it is made into hay in the ordinary way. (From New York State College of Agriculture, Cornell University.)

436. Pros and cons of hay-crop silage.—Many experiments have been conducted in recent years to determine the feeding value of hay-crop silage, and especially to compare it with corn silage or with hay. These studies have shown that one of the chief advantages of hay-crop silage is that it can be made when the weather is so rainy that it is impossible to make good field-cured hay.

Part of the first cutting of legume or mixed legume-grass hay can be ensiled earlier than the usual stage for making hay, when the crop has a very high feeding value per ton of dry matter. A larger second crop of hay can then generally be obtained, which can be made into good hay, as the weather in late summer is usually more favorable for field curing.

Making part of the first cutting into silage early helps to distribute the labor of harvesting the hay crops, and it aids in controlling weeds.

By ensiling hay crops, good silage can readily be provided in regions where the climate is too cool or the growing season is too short for corn or the sorghums to thrive. Where fields are subject to severe erosion, growing hay crops for silage instead of corn or sorghum largely prevents erosion.

Double use can be made of a silo

when it is filled in the fall with corn or other silage for winter feeding, and then filled again early in the summer with first-cutting hay crop. This silage can be fed during the summer as a supplement to pasture when the pasturage becomes scanty.

It has been shown in the previous chapter that the total losses of dry matter and of nutrients are generally slightly less when a hay crop is ensiled by a good method than when it is made into field-cured hay, even in good weather. (398) The difference is great in the case of carotene. In rainy weather the loss of dry matter and of nutrients is much greater in field-cured hay than in silage.

Another advantage of hay-crop silage is that stock usually eat it with less wastage than in the case of hay of ordinary quality.

One of the disadvantages of hay-crop silage is that it often has a very penetrating and disagreeable odor, even when made by one of the special methods that have been described. This is more objectionable to humans than to livestock. Usually stock like hay-crop silage when they become used to it, but sometimes they will not consume as much as of corn silage. With hay-crop silage there may be more trouble in very cold weather from freezing next to the silo wall than with corn silage.

The cost of storing a hay crop as silage is often greater than the cost of making it into hay in good hay-making weather, because of the large amount of water that must be handled in the green crop. In general, there is little or no advantage in ensiling hay crops in a region where the climate is such that it is generally easy to make them into hay of good quality. It must always be remembered that good silage cannot be made from any crop that would not make satisfactory hay if it could be cured satisfactorily.

In ensiling hay crops, the forage should be cut fine, as it then packs quickly and closely, forcing out the air. For wilted or rather mature forage, the cutter should be set for the shortest cut available. An unwilted crop, high in water, need not be cut so fine, except towards the top of the silo.

When the wilting method is used in making hay-crop silage, the top few feet in the silo should not be wilted, for the wet, heavy forage will pack better and reduce surface spoilage. Also, it is best to add molasses or another preservative to the top portion.

A silo for hay-crop silage must be well built and strongly reinforced to withstand the great lateral pressure as the silage settles.

437. Nutrients in hay-crop silage.—The percentage of dry matter in hay-crop silage varies widely, depending on whether or not the crop was wilted before being ensiled and also on the stage of maturity. Separate averages are therefore given in Appendix Table I for wilted silage of various kinds and for unwilted silage, so far as sufficient data are available.

In general, hay-crop silage is appreciably lower in total digestible nutrients, and especially in net energy, than well-eared corn silage which has the same percentage of dry matter. This is because hay-crop silage lacks the large amount of grain that well-eared corn silage contains. Experiments have also shown that hay-crop silage is a little lower in total digestible nutrients, on the dry basis, than good hay made from the same crop.[22]

On the dry basis, hay-crop silage is similar in content of total digestible nutrients to immature corn silage or corn silage with only a few ears. Because of the lower content of total digestible nutrients and net energy in hay-crop silage, compared with well-eared corn silage, it may be necessary to feed high-producing animals a somewhat larger allowance of concentrates with hay-crop silage. This is especially apt to be the case with fattening cattle or lambs.

The difference in total digestible nutrients may be entirely or largely offset by the fact that most hay-crop silage is much higher in protein than corn or sorghum silage. Less protein supplement is therefore needed with hay-crop silage. Often, no protein supplement at all is re-

quired with hay-crop silage, while it would be necessary with corn or sorghum silage. This is an important point when protein supplements are decidedly more expensive than farm grain, but it is frequently overlooked.

Hay-crop silage of good quality is much richer in carotene than field-cured hay made from the same crop. (**196**, Appendix Table V) It also has much more carotene than corn or sorghum silage.

While field-cured hay usually supplies considerable vitamin D, hay-crop silage that has not been wilted has very little. This is because green forage crops have practically no vitamin D, but contain ergosterol, from which the vitamin is formed during field curing through the action of the ultra-violet light in the sunlight. (**201**, **204**) Hay-crop silage that has been wilted in the field may have sufficient vitamin D to protect calves against rickets when they have no other source of the vitamin.

Because hay-crop silage does not supply much vitamin D, it is not advisable to use it as the only roughage for cattle or sheep throughout the winter, unless they are exposed to considerable direct sunlight or are fed a vitamin D supplement.

438. Hay-crop silage for dairy cattle.—Hay-crop silage, or "grass silage," is used in this country much more extensively for dairy cows and heifers than for other classes of stock. A great number of experiments have therefore been conducted by our experiment stations to determine the value of hay-crop silage for dairy cattle and to find the best ways of using it.[23] From a study of the results of these many investigations, the following conclusions can be drawn:

When hay-crop silage is added to a ration of good hay and concentrates, the milk production of cows is usually increased slightly. This is because a good succulent feed tends to raise the milk yield somewhat. (**524**) Whether or not the increase will be marked will depend chiefly on the quality of the hay. If the hay is rather poor, there will be a decided benefit from the addition of silage to the ration.

Experiments have shown that hay-crop silage is generally worth more, per 100 lbs. of dry matter, than good hay made from the same crop. This is in spite of the fact, mentioned previously, that the content of total digestible nutrients in hay-crop silage is a trifle less, on the dry matter basis, than in good hay made from the same crop.

As has been stated previously, the losses of dry matter and of nutrients are generally a little less when a hay crop is made into good silage than when the crop is field-cured into hay. In rainy weather there is considerable difference in favor of silage.

In extensive experiments by the United States Department of Agriculture, in which both the losses of dry matter and nutrients and the actual feeding value of the forage were considered, wilted alfalfa silage produced 5 per cent more milk per acre than field-cured hay made in good weather. The value of the silage per acre was 31 per cent greater than that of field-cured hay which was damaged by rain.

The wilted silage had about the same feeding value per acre as barn-dried hay, ranking slightly above barn-dried hay made with unheated air and a trifle below barn-dried hay made with heated air.

These and other experiments show that about the same feeding value per acre for dairy cows is secured when a hay crop is made into silage by a good method as when it is barn-dried. The choice between the two methods should therefore depend on the relative cost and convenience on any particular farm.

In some experiments hay-crop silage has been fully equal in value per ton for milk production to well-eared corn silage containing the same percentage of dry matter. However, in other trials in which equal amounts of concentrates have been fed, there has been a tendency for the milk yield to be a trifle lower on hay-crop silage, or for the cows not to maintain their live weights quite so well. Such a tendency can be prevented by increasing the allowance of

concentrates somewhat, to make up for the lack of grain in hay-crop silage.

This advantage of well-eared corn silage may be off-set by the fact that legume or legume-grass silage is much richer in protein. Therefore, decidedly less protein is needed in the concentrate mixture than with corn or sorghum silage. Often dairymen do not fully take this difference into consideration when substituting hay-crop silage for corn or sorghum silage.

The high milk production which can be secured on home-grown feed by the use of silage, hay, and pasture rich in legumes is well shown by the results obtained by an Illinois dairyman.[24] His 21-cow herd averaged 525 lbs. of fat a year without the feeding of any purchased concentrate. A mixture of only ground corn and oats, with minerals, was fed at a moderate rate. The excellent production was due to the fact that in winter the cows were fed all the legume-grass silage (made with ground corn as a preservative) and all the excellent mixed hay they would clean up, and in summer they had good legume-grass pasture, with a little hay supplied in addition.

Hay-crop silage can be used as the only roughage for dairy cows or heifers, but the best results are usually secured when it is fed in combination with some hay. When cows are fed only hay-crop silage for roughage, they will generally not consume as much roughage, on the dry basis, as when they are fed both silage and hay. The only exception seems to be with hay-crop silage that is wilted so that it has a high content of dry matter. Such silage is, however, apt to mold unless great care is taken to cut the forage very fine when it is ensiled, and to tramp it well in the silo.

When hay-crop silage of the usual type is fed to dairy cows as the only roughage, it is generally necessary to feed more concentrates than usual. If this is not done, the cows are apt to drop in milk production or to lose body weight, because of a smaller intake of nutrients.

If there is a more abundant supply of hay-crop silage than there is of hay, the amount of hay can be reduced somewhat, with entirely satisfactory results. Dairy cows are ordinarily fed at least 1 lb. of hay daily per 100 lbs. live weight. However, good results are secured when only 5 to 7 lbs. of well-made hay are fed per head daily, along with all the silage the cows will eat and the usual amount of concentrates.

Hay-crop silage is an excellent supplement to pasture for dairy cows, being equal to good hay for this purpose in a Georgia experiment.[25] Feeding the silage to cows on pasture was not unduly laxative, and milk production and live weights were maintained as well as when hay was fed on pasture.

When part of the first cutting of hay is made into silage, excellent use can often be made of the silage for supplementing scanty pasture in midsummer. Then the silo can be filled again with corn or sorghum silage in the fall.

Because hay-crop silage usually has much more carotene than field-cured hay or than corn or sorghum silage, the vitamin A value of winter milk is increased decidedly when hay-crop silage is fed. Also, the milk, especially of Guernseys and Jerseys, is yellower in color, because of the greater carotene content.

If hay-crop silage is fed only after milking and in a well-ventilated stable, the strong odor it often has does not injure the flavor of milk or of dairy products. Indeed, the feeding of hay-crop silage under proper conditions may improve the flavor of milk and also reduce the tendency for oxidized flavor to develop in pasteurized milk. Care should always be taken not to leave any uneaten silage in the manger to spoil, and not to have piles of silage in the stable at milking time.

Hay-crop silage can be used for growing dairy heifers in the same manner as for dairy cows. It is shown in Chapter XXVII that the results of the experiments have differed greatly in which hay-crop silage has been compared with good hay for heifers. (1135) Often heifers will consume much less dry matter than normal, if fed hay-crop silage as the only roughage or with but a small

allowance of hay. They will then need a greater amount of concentrates to make good growth.

Hay-crop silage that has not been wilted in the field is usually too low in vitamin D to protect calves against rickets, when they have no exposure to sunlight. On the other hand, wilted silage may supply sufficient of the vitamin. (204)

439. Hay-crop silage for beef cattle.—In several experiments with fattening cattle fed a liberal amount of grain, hay-crop silage has been equal in value per ton to corn silage containing a similar percentage of dry matter.[26] On the other hand, when cattle are fattened chiefly on roughage, with only a small amount of concentrates, the lack of grain in hay-crop silage is a decided disadvantage.

Fattening cattle need considerable grain or other concentrates to make rapid gains and become well fattened. Therefore on a high-roughage ration it is generally necessary to feed a larger amount of concentrates with hay-crop silage than with well-eared corn silage, to produce as rapid gains and as good finish.

This disadvantage is partly offset by the fact that most hay-crop silage is considerably higher than corn silage in protein. Consequently, there may be no need to feed a protein supplement with hay-crop silage, even though a supplement is needed when corn silage is used.

In a recent Ohio trial yearling steers gained 2.0 lbs. a day on only corn silage supplemented with 1.5 lbs. of soybean oil meal per head daily.[27] To produce equal gains it was necessary to give steers fed hay-crop silage 8 lbs. of corn-and-cob meal a day. In this trial hay-crop silage was worth only 52 per cent as much per ton as corn silage.

In each of 4 Michigan experiments one lot of cattle was fattened on a ration of corn silage, legume or mixed hay, and protein supplement, with an average of only 1.6 lbs. corn grain per head daily in addition.[28] Another lot was fed hay-crop silage (largely alfalfa), with enough corn grain to produce gains equal to the first lot. This required 8.7 lbs. of corn per head daily. In these trials the hay-crop silage was worth 84 per cent as much a ton as the corn silage.

A third lot of cattle in each experiment was fed alfalfa hay and enough corn grain to produce gains equal to the first lot. This required about the same amount as for the cattle fed hay-crop silage. On the average, hay-crop silage was worth 58 per cent as much a ton as alfalfa hay.

In New York and West Virginia experiments satisfactory results were secured when beef cows were wintered on a limited amount of good hay plus either hay-crop silage or corn silage.[29] In the New York trials the hay-crop silage, on the dry-matter basis, was worth 80 per cent as much per ton as corn silage. In the West Virginia trials, where equal amounts of dry matter were fed, the cows gained slightly more on corn silage. In other West Virginia experiments beef cows gained a little more when fed both hay-crop silage and hay than when fed either hay or the silage alone.[30]

Experiments have shown that hay-crop silage usually has a much lower value for wintering beef calves than for beef cows. Beef calves make satisfactory gains when wintered on only good alfalfa or other legume hay, or else on corn or sorghum silage plus a small amount of protein supplement. However, if fed only hay-crop silage the gains are generally unsatisfactory, though such silage has plenty of protein.[31]

To produce good gains on hay-crop silage, it is necessary to feed the calves 2 to 3 lbs. or more of grain or other concentrates. In New York tests hay-crop silage was worth only 57 per cent as much per ton as corn silage, on equal dry matter basis, in comparison with 80 per cent as much for beef cows.[32] The difference was probably due to the fact that growing calves need a ration richer in net energy than do mature cows being wintered.

440. Hay-crop silage for sheep.—Hay-crop silage is a satisfactory substitute for corn silage or for hay in feeding sheep. It is not generally used as the only roughage, but is best fed in combination with hay. However, in Kentucky,

Michigan and Ohio experiments satisfactory results were secured when pregnant ewes and other sheep were wintered on hay-crop silage as the sole roughage.[33] Ewes thus fed will eat 10 to 12 lbs. of silage per head daily. On the average, hay-crop silage was worth about 40 per cent as much per ton as hay in feeding value.

Since hay-crop silage lacks the considerable amount of grain there is in well-eared corn silage, breeding ewes or fattening lambs may need more grain when hay-crop silage replaces corn silage. However, a protein supplement may be needed with corn silage and not with hay-crop silage, which usually has much more protein.

In South Dakota experiments fattening lambs made equal gains when fed rations of corn grain, protein supplement, a little hay, and either alfalfa silage or corn silage.[34] The alfalfa silage was worth slightly less per ton than the corn silage. Less satisfactory results were secured in New Mexico trials where alfalfa silage was used as the only roughage for fattening lambs.[35]

441. Hay-crop or grass silage for other stock.—Hay-crop silage is not commonly fed to horses, but it can be used in the same manner as corn silage. (**528**) Special care should be taken not to feed any spoiled silage to horses.

Legume silage can be used instead of legume hay as a vitamin A supplement for swine. However, it has but little vitamin D, unless it has been wilted in the field. It is therefore generally better to include good-quality, field-cured alfalfa or other legume hay in the winter rations for swine.

Grain can be saved by feeding brood sows hay-crop silage in winter, just as with legume hay.[36] However, in Minnesota tests feeding hay-crop silage to sows after farrowing tended to cause scours in the nursing pigs.[37]

Silage made from alfalfa, clover, or other legumes, or from immature grass is sometimes fed to hens or other poultry, instead of using alfalfa meal as a vitamin A supplement.[38] When rations of hens contain the usual amounts of alfalfa meal and other vitamin supplements, the addition of such silage does not generally cause any improvement. Feeding more than 3 lbs. of hay-crop silage daily per 100 hens may produce dark-colored or greenish yolks. After hens become accustomed to silage, they sometimes will eat as much as 10 to 15 lbs. daily per 100 birds. Chicks do not eat enough hay-crop silage to provide sufficient riboflavin.

For poultry, silage is occasionally made in barrels or steel drums. The forage must be well packed and a cover should be used, with a heavy weight on top. This method takes much labor per ton of silage.

II. Silos and Filling the Silo

442. Requisites of a good silo.—To preserve silage best, an above-ground silo should have the following characteristics:

1. *Air tight walls.* The walls must prevent the entrance of air and the doors must fit snugly. If air enters, molds will grow, spoiling the silage.

2. *Cylindrical shape.* In the early silos, which were rectangular, it was exceedingly difficult to pack the forage tightly enough in the corners to prevent spoilage. The cylindrical silo has no corners, the sides are strong and unyielding, and it provides the largest possible cubic capacity for a given amount of building material.

3. *Smooth, perpendicular, strong walls.* Unless the walls of the silo are smooth and perpendicular, cavities will form along the walls as the mass settles, and the adjacent silage will spoil. The walls must be strong and rigid, for while the silage is settling a great outward pressure is developed. This is considerably greater in the case of hay-crop silage than with corn silage.

4. *Depth.* It has been emphasized previously in this chapter that the percentage loss of nutrients by surface spoilage is much less in a deep silo than in a shallow one. (**426**)

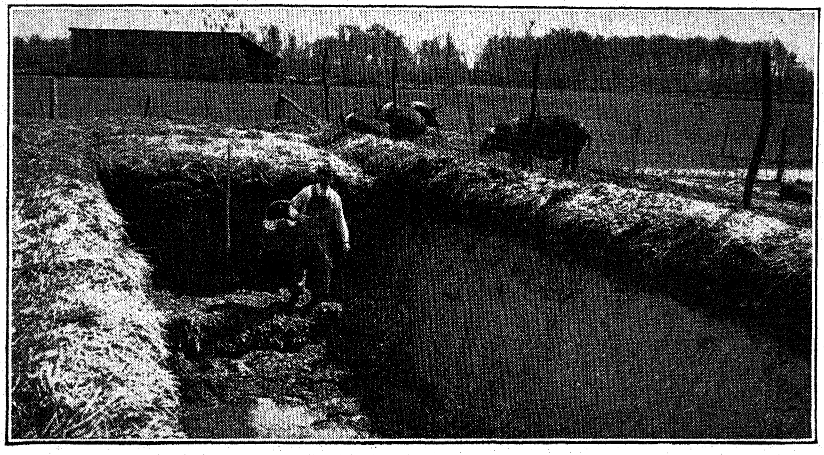
443. Types of silos.—Most above-ground silos in this country are constructed of wood, concrete staves, or glazed tile. Occasionally, silos are built

of solid concrete, brick, or galvanized sheet iron or steel. The choice between the various types of silos will depend on local conditions.

Especially in the drier regions, wide use has been made of trench silos during recent years. Where the soil is well drained, these provide a cheap and satisfactory means of ensiling crops. The losses of nutrients in trench silos are considerably greater than in the case of deep cylindrical silos, but this is more or less offset by the small cost. Occasionally, pit silos are used instead of trench silos.

On account of the shallowness, the trench silo and stacked the silage above this. Occasionally, instead of making a trench in the ground, earth is piled on each side so as to make an above-ground trench.

Temporary silos are occasionally made of slat or picket fencing, such as is used for snow fences. This is lined with a tough reinforced paper made for the purpose. "Snow-fence" silos are not well suited for ensiling hay crops, because heavy spoilage is apt to occur during summer in such silos.[39] They are more satisfactory with corn or sorghum silage.



A Trench Silo Provides Cheap Storage

Where the soil is well drained, a trench silo provides cheap storage for forage, but the losses of nutrients are higher than in deep cylindrical silos.

forage must be packed very thoroughly in a trench silo by driving a tractor or a team of horses back and forth over it, and when filling is completed the surface should be covered with wet straw or with straw and earth. Feeding is begun at one end, the silage being removed in vertical slices of a size which can be fed out in about two days.

Especially where the soil is not well enough drained for a trench silo, silage is sometimes made in above-ground large and long stacks, well compacted by running the trucks over the mass. Losses are apt to be higher than in a trench silo. Some farmers have made a shallow

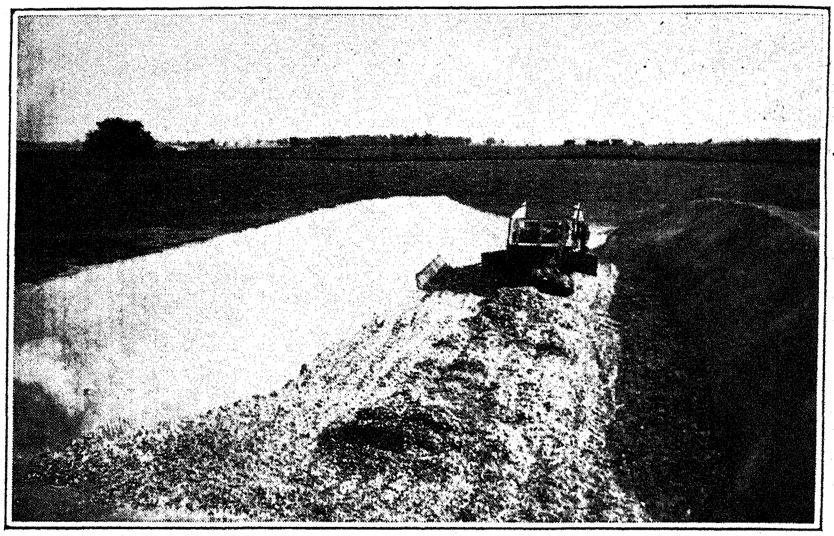
Gas-tight silos have been developed, which are made of glass-coated steel plates, and which have a mechanism at the bottom for removing the silage daily. In a test by the United States Department of Agriculture a comparison was made of grass silage in such a silo and in an ordinary tower silo.[40] Except for the top surface spoilage in the ordinary silo, there was no appreciable difference in the loss of dry matter or digestible nutrients in the two silos, or in the feeding value of the silage.

444. Filling the silo.—In ensiling forage it should be chopped fine by a silage cutter. Finely-chopped forage

packs more densely, it makes better silage, and the loss of nutrients is reduced to a minimum. Also, the silage can be removed much easier if the forage is chopped.

In this country silage cutters are generally set to cut the forage into pieces not over one-half inch long. For corn in the early-dent stage, a half-inch cut is satisfactory. For more mature corn and for hay-crop silage, a one-quarter inch cut is best, as the forage packs better.

is directed toward the center of the silo. The forage is then allowed to "cone up" as it falls. Sometimes a man levels it off after each load, but others do no levelling except toward the top of the silo. To avoid a large amount of spoilage at the top, it is important that for the last few feet the silage be levelled off and thoroughly tramped. Good results are secured by this method with corn or sorghum forage, if it contains sufficient water to pack well, but if it is a little



A LARGE ABOVE-GROUND TRENCH SILO

The cut forage is packed firmly by the trucks as the silo is filled. Such a trench silo can be used where the soil is not well enough drained for a regular trench silo.

dry, the silage is apt to be poor, especially near the wall. Thorough distributing and tramping is advisable with hay-crop silage.

The safest plan to insure good silage is to have a reliable man in the silo as it is filled, to distribute the forage uniformly by moving the flexible distributor pipe. In walking about, he will also help pack the forage. Toward the top of the silo the material should be tramped especially well near the wall, as the friction with the wall retards settling. Some advise keeping the center higher than the outside while filling the upper part of the silo, believing that this lessens the tendency of the silage to draw away from the wall as it settles.

To save labor, the plan is sometimes used of tying the distributor pipe so it

No matter what method is followed, if the forage is too dry to pack well when it is ensiled, water should be added. This may be done by running it into the blower-fan case or into the blower pipe just above the blower. If the water is under sufficient pressure, it may be allowed to run into the flexible distributor pipe in the silo, or the man who tramps the forage can carry the hose and wet the forage as he packs it.

The forage will settle considerably

after the silo is filled, and more may then be put in, any spoiled surface material being first removed. If feeding is not to begin immediately, the surface should be wet down thoroughly and tramped well several times the first week, when the rotting forage on top will form a layer that protects the rest. To lessen the waste, it is well to remove the ears from the last few loads of corn forage and to cover the top with a foot or so of cheap refuse, such as straw or weeds thoroughly soaked with water. Sometimes oats are sown on the surface. On growing, the roots form a dense mat which aids in keeping out the air.

The loss at the surface can be reduced to a minimum if the forage is covered (after it is levelled, thoroughly wet down, and well tramped) with cheap roll-roofing, the joints being lapped about 4 inches and the ends turned up against the side wall 4 or 5 inches. Then the roofing is covered with a few inches of silage, wet straw, sawdust, or other material. Heavy, strong wrapping paper, treated with lubricating oil, can be used in place of roll-roofing. Silo seals, made of plastic or rubberized fabric, have also been developed for reducing the surface spoilage.

If desired, feeding the silage can start immediately after the forage is ensiled. When feeding starts later, any spoiled material should always be removed from the top of the silage and put where stock cannot eat it.

445. Danger from carbon dioxide, or nitrogen dioxide.—On going into a silo after an intermission in filling or for a few days after filling, one should always guard against danger from carbon dioxide. This gas, which is heavier than air, may accumulate near the surface of the silage so that there will not be enough oxygen in the air for life. If a lighted lantern or candle lowered into the silo goes out, it is unsafe for one to enter. Opening a door near the surface of the silage will allow the carbon dioxide to escape. Before entering, agitate the air by operating the blower for a few minutes or by swinging a blanket vigorously.

Very rarely, poisonous yellow nitrogen dioxide gas is formed in silage soon after filling, apparently being produced from nitrates in the forage.[41] The gas is heavier than air and may accumulate near the surface of the silage or in the silo chute. Operating the blower for a few minutes before entering the silo will drive out any of this gas as well as carbon dioxide.

446. Weight of silage and capacities of silos.—Several investigations have been conducted to determine the weight of corn silage per cubic foot at various depths in cylindrical silos and the capacities of silos of various sizes, including studies by the United States Department of Agriculture and by the Kansas, Minnesota, Missouri, Nebraska and Wisconsin Stations.[42] These experiments show that silage is much more compact and heavier as the depth from the surface increases. The weight per cubic foot at any depth will vary considerably, depending especially on the percentage of water in the crop when ensiled and the amount of grain in it.

The experiments by the United States Department of Agriculture were with well-eared corn forage, ensiled at the early dent stage and having about the average percentage of water for well-eared corn silage. In these studies the average weight of a cubic foot of corn silage at the surface foot was 17.7 lbs.; at a depth of 5 feet, 39.8 lbs.; at 10 feet, 47.1 lbs.; at 15 feet, 50.5 lbs.; at 20 feet, 52.4 lbs.; at 25 feet, 53.7 lbs.; at 30 feet, 54.4 lbs.; and at 35 feet, 54.8 lbs.

The average weight of the silage for the whole depth was 31.6 lbs. per cubic foot for the first 5 feet, 38.1 lbs. for a depth of 10 feet, 41.8 lbs. for a depth of 15 feet, 44.3 lbs. for a depth of 20 feet, 46.1 lbs. for a depth of 25 feet, 47.4 lbs. for a depth of 30 feet, and 48.5 lbs. for a depth of 35 feet.

The following table shows the estimated capacity of silos of various sizes, according to these investigations, for well-eared corn silage ensiled in the early dent stage, cut in one-quarter inch lengths, well-tramped during filling of the silo, and with the silo refilled once

after settling for one day. The depth indicated is the actual depth of the settled silage, and not the height of the silo.

For corn silage differing from this type, the following changes should be made from the capacities shown in the table:

1. If the corn is well eared but immature, add 5 per cent to the number of tons shown. If it has only a fair number of ears, deduct 5 per cent, and if it has few ears or none, deduct 10 per cent.

2. If the corn grain is almost fully dented, deduct 5 to 10 per cent.

3. If the corn grain is fully dented and hard, deduct 15 to 20 per cent.

4. If the corn is cut in 5/8 to 3/4 inch lengths or longer, deduct 5 per cent.

The capacity of a silo for sorghum silage containing a good proportion of grain is about the same as for corn silage. Hay-crop silage is heavier than corn silage that contains the same percentage of dry matter. On the other hand, if the hay crop is wilted before ensiling, so that the percentage of dry matter is 30 per cent or more, the silage may be no heavier than corn silage. Sunflower silage is much heavier than corn silage.

Hay-crop silage has been found to exert a much greater lateral pressure on the silo wall during settling than does corn silage having the same moisture content. Silos for hay-crop silage therefore need additional reinforcing to withstand this pressure. This is also the case with sunflower silage.

447. Estimating the amount of silage in a silo.—To estimate the amount of silage remaining in a silo after part has been fed out, find the actual depth left and estimate the original total depth of silage after settling. Then compute the amount as follows: Let us suppose that 10 feet of silage are left in a silo having a diameter of 14 feet, and that after settling, the entire depth of silage was about 28 feet before feeding started.

From the table we find that at first the silo contained 101 tons. The first 18 feet of silage, which were fed out, contained about 60 tons, according to the table. The difference, or 41 tons, is the approximate weight of the silage left.

Tons of settled corn silage in cylindrical silos

Inside diam. in feet	Depth of silage in feet											
	4	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**
10	5	8	11	15	19	23	27	31	35	39	43	47
12	7	11	16	22	27	33	38	44	50	56	62	68
14	9	15	22	29	37	44	52	60	68	76	85	93
16	12	20	29	38	48	58	68	79	89	100	110	121
18	15	25	37	49	61	74	86	100	113	126	140	154
20	18	31	45	60	75	91	107	123	139	156	173	190

	Depth of silage in feet											
	28	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**
10	52	56	60	64	..	..	..	..	..	..	..	..
12	74	80	87	93	..	..	..	..	..	..	..	..
14	101	110	118	126	135	143	152	..	..	..	..	..
16	132	143	154	165	176	187	198	209	220	..	..	..
18	167	181	195	209	223	237	251	265	279	293	307	320
20	206	224	241	258	275	292	310	327	344	361	378	396

448. Proper size of silo.—The diameter of the silo should depend on the number and kind of animals to be fed from it, and its height on the length of the feeding period. The silo should be of such diameter that in the cooler part of the year at least 1.5 inches, and preferably 2 inches, of silage will be removed from the entire surface daily to prevent spoilage. When silage is used for summer feeding, somewhat more should be removed daily.

The size of silo required may be computed from the length of the feeding period and the amount required

daily for the different kinds of stock, as shown previously in this chapter. Knowing the number of animals of each kind to be fed, the entire amount of silage which will be consumed daily may be ascertained. The maximum diameter which the silo should have may then be determined from the following:

Two inches in depth of ordinary corn silage average about 7.9 lbs. per surface square foot in a silo filled to a depth of 30 feet. To use 2 inches daily from the surface, approximately the following amounts must be fed from silos of various diameters: Diameter 10 feet, 620 lbs. silage; 12 feet, 895 lbs.; 14 feet, 1,215 lbs.; 16 feet, 1,590 lbs.; 18 feet, 2,010 lbs.; and 20 feet, 2,480 lbs.

When the maximum diameter which the silo should have has thus been determined, the total amount of silage required for the desired feeding period may be computed, and the dimensions for a silo of this capacity found by referring to the table given previously. It should be borne in mind that silage in a relatively deep silo keeps better than in a shallow one, as has been pointed out before. Also, when a silo is more than 18 or 20 feet in diameter, more labor is required in carrying the silage to the silo door as it is removed for feeding.

QUESTIONS

1. State 8 advantages of silage for livestock feeding.
2. Discuss the use and value of silage for dairy cattle, beef cattle, and sheep.
3. Under your local conditions should a dairy farmer raise silage for his cows, or should he use hay as the only roughage?
4. Describe in detail the changes that occur when a green crop is ensiled.
5. Discuss the efficiency with which nutrients are preserved in silage, stating the kinds of losses that occur and the approximate percentage of dry matter that is lost.
6. What characteristics should a good silage crop have?
7. Discuss the suitability of the following crops for silage: Corn, the sorghums, the small grains, alfalfa.
8. What special methods are used to produce better silage from hay crops? Describe 5 methods and state the quality of silage produced by each.
9. Discuss the advantages and disadvantages of hay-crop silage in comparison with corn silage and with hay.
10. Compare the content of hay-crop silage and corn silage in total digestible nutrients, net energy, protein, and carotene.
11. What is the relative vitamin D content of hay-crop silage and of field-cured hay?
12. Discuss the value of hay-crop silage for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) swine; (e) poultry.
13. State four requisites of a good silo.
14. State the advantages and disadvantages of trench silos.
15. Discuss the various methods of filling a silo with corn forage. Under what conditions might you allow the forage to "cone up" in the silo?
16. How can surface spoilage of silage be lessened?
17. How can you determine approximately how much silage is left in a silo after part of it has been fed out?

REFERENCES

1. Peterson, Hastings, and Fred, Wis. Res. Bul. 61; see also: Nevens, Ill. Bul. 391; Neidig, Iowa Res. Bul. 16; Lamb, Iowa Res. Bul. 40; Lamb, Iowa Bul. 168; Kan. Rpts. 1924–26, 1928–30; Hunter, Penn. Bul. 170; Hunter, Penn., Jour. Agr. Res., 21, 1921, pp. 767–789; Kroulich et al., U.S.D.A., Jour. Dairy Sci., 38, 1955, pp. 256–272.
2. Hastings, Wis. Bul. 388.
3. See the review by Monroe, Hilton, Hodgson, King, and Krauss, Jour. Dairy Sci., 29, 1946, pp. 239–256; see also: Woodward and Shepherd, U.S.D.A. Tech. Bul. 611; McCalmont, Krueger, and Eby, N.J. Bul. 731.
4. Archibald and Gunness, Mass., Jour. Dairy Sci., 28, 1945, pp. 321–324; McCalmont, Krueger, and Eby, N.J. Bul. 731; Perkins, Ohio Bul. 370; Byers and Jones, Ore. Cir. of Inf. 496; Shaw, Wright, and Deysher, U.S.D.A. Bul. 953.
5. King, N.J. Buls. 704, 708; Perkins, Ohio Bimo. Bul. 220, Jour. Dairy Sci., 26, 1943, pp. 545–551.
6. Osland, Colo. Bul. 380; Ragsdale and Turner, Mo. Buls. 179, 189, Mo. Res. Bul. 65; Cook, N.J. Bul. 19; Armsby, Penn. Rpt. 1889; King, Wis. Bul. 59; Woll, Wis. Rpt. 1891.
7. Wilson and Webb, N.Y., Jour. Dairy Sci., 20, 1937, pp. 247–263.
8. Wilson, N.Y., Jour. Dairy Sci., 18, 1935, pp. 317–325.
9. Stone et al., Penn. Bul. 444.
10. Nevens and Dungan, Ill. Bul. 494.
11. Woodward, U.S.D.A. Leaflet 238; Dexter, Mich. Quar. Bul. 34, 1952, No. 4; Parks, Ohio, Jour. Amer. Soc. Agron., 33, 1941, pp. 325–335; Monroe and Perkins, Ohio, Jour. Dairy Sci., 22, 1939, pp. 37–49.
12. King, N.J., Jour. Dairy Sci., 26, 1943, pp. 975–981.

13. Knodt, Skaggs, and Williams, Penn. Bul. 552; see also: Archibald, Blaisdell, and Kuzmeski, Mass. Bul. 467; Teeri, Josselyn, Colovos, and Keener, N.H., Jour. Anim. Sci., 12, 1953, pp. 15–18; Keener, Teeri, Harrington, and Baldwin, N.H., Jour. Dairy Sci., 36, 1953, pp. 1205–1211; Mather, Eby, and Bender, N.J. Rpt. 1950; Rogers et al., Ohio Bul. 725; Reaves and Sandy, Va. Rpt. 1950; Dufour, Niedermeier, Zehner, and Crowley, Wis., Jour. Dairy Sci., 37, 1954, pp. 52–57; Shepherd et al., U.S.D.A., Jour. Dairy Sci., 33, 1950, p. 384.
14. Cowan, Bratzler, and Swift, Penn., Science, 116, 1952, p. 154; Bratzler, Cowan, et al., Penn., Jour. Anim. Sci., 11, 1952, pp. 782–783; 12, 1953, p. 939; 14, 1955, p. 1237; Alderman, Cowan, Bratzler, and Swift, Penn., Jour. Dairy Sci., 38, 1955, pp. 805–810.
15. Kendall et al., Ill., Jour. Anim. Sci., 14, 1955, p. 1212; Allen and Ward, Iowa, Jour. Dairy Sci., 38, 1955, p. 625; Allen, Porter, and Jacobson, Iowa, Jour. Anim. Sci., 14, 1955, p. 1234; Woolfolk, Thompson, and Grainger, Ky., Jour. Anim. Sci., 13, 1954, p. 1014; Decker, Plummer, Edgerly, and Leonard, Me. Mimeo. Rpt. 42; Archibald and Kuzmeski, Mass., Jour. Dairy Sci., 37, 1954, pp. 1283–1290; Little, Mich. Quar. Bul., 37, 1954, No. 1; Gordon et al., U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 602–603; 37, 1954, p. 659; Gordon, U.S.D.A. Agr. Res., 3, 1954, No. 3.
16. Allred, Kennedy, Wittwer, Trimberger, Reid, and Loosli, N.Y. (Cornell) Bul. 912; Wittwer, Trimberger, Kennedy, Allred, Reid, Loosli and Turk, N.Y. (Cornell) Bul. 913.
17. Gardner et al., Ill., Jour. Anim. Sci., 14, 1955, p. 1212; Gordon, U.S.D.A. Agr. Res., 3, 1954, No. 3.
18. Archibald and Parsons, Mass. Bul. 425; Wyant, Mich. Rpt. 1920; N.J. Rpt. 1943; Ore. Rpt. 1918–20; Stone et al., Penn. Bul. 444; Peterson et al., Wis. Bul. 455.
19. Wyant. Mich. Rpt. 1920; Withycombe and Bradley, Ore. Bul. 102; Peterson, Hastings, and Fred, Wis. Res. Bul. 65.
20. Woll and Hoffman, Cal. Rpts. 1922, 1923; Mangold, Germany, Handb. Ernährung u. Stoffwechsels, Vol. 1, pp. 368–370.
21. Gorini, Italy, Atti accad. Lincei, 3, 1926, pp. 629–632; Samarani, Italy, Hoard's Dairyman, 63, 1922, p. 806; Hastings, Fred, and Peterson, Wis. Bul. 362.
22. Brundage and Sweetman, Alaska, Jour. Anim. Sci., 13, 1954, p. 1007; Keener et al., N.H. Cir. 77; Newlander, Ellenberger, Camburn, and Jones, Vt. Buls. 430, 459; Camburn, Ellenberger, Jones, and Crooks, Vt. Buls. 494, 509.
23. Brundage and Sweetman, Alaska, Jour. Anim. Sci., 13, 1954, p. 1007; Ariz. Rpt. 1941; Morrison and Deal, Ga., Jour. Dairy Sci., 35, 1952, p. 501; Hansen et al., Id., Jour. Dairy Sci., 35, 1952, p. 481; Nevens, Harshbarger, and Kendall, Ill. Cir. 605; Wilbur, Waugh, Hauge, and Hilton, Ind. Cir. 372; Lundquist, Hill, and Wilbur, Ind., Rpt. 66; Hill, Walker, and Lundquist, Ind., Jour. Anim. Sci., 13, 1954, pp. 1008–1009; Porter, Iowa Farm Sci., 7, 1953, Nos. 9, 11; Porter and Allen, Iowa Farm Sci., 9, 1954, No. 4; Fountaine, Parrish, and Bartley, Kan. Rpt. 1948–1950; Berry and Turk, Md. Bul. A13; Archibald, Mass. Bul. 467; Little, Norden, and Wolcott, Mich. Quar. Bul. 36, 1953, No. 2; Huffman, Duncan, Dexter, and Chance, Mich. Quar. Bul., 36, 1954, No. 4; Petersen, Fitch, and Allen, Minn., Jour. Dairy Sci., 20, 1937, pp. 429–430; Allen and Fitch, Minn. Bul. 360; Miss. Rpt. 1944; Keyes and Smith, Mont., Jour. Dairy Sci., 37, 1954, p. 657; Headley, Nev. Rpt. 1949; Keener et al., N.H. Cir. 77, N.H. Buls. 382, 402; Bender and Tucker, N.J. Cir. 374; Bender, N.J. Bul. 695; King, N.J. Buls. 704, 708, 713, 722, 723; Savage et al., N.Y. (Cornell) Rpts. 1938, 1939, 1940, 1941; Turk, S. H. Morrison, Norton, and Blaser, N.Y. (Cornell) Bul. 874; Hayden et al., Ohio Bul. 656; Monroe et al., Ohio Bul. 695; Bechdel, Stone, Williams, and Murdock, Penn. Bul. 411; Henderson and Norton, R.I. Bul. 311; Mitchell and Wise, S.C. Rpt. 1943; Wilson and Bartle, S.D. Farm and Home Res., 5, 1953, No. 1; 6, 1954, No. 1; Lush, VanHorn and Whitaker, Tenn. and U.S.D.A., Jour. Anim. Sci., 13, 1954, pp. 1009–1010; Newlander, Ellenberger, et al., Vt. Buls. 430, 485; Camburn, Ellenberger, and Jones, Vt. Bul. 482; Camburn, Ellenberger, Jones, and Crooks, Vt. Buls. 494, 509; Pratt and Holdaway, Va. Bul. 353; Peterson et al., Wis. Buls. 438, 442; Bohstedt, Peterson, and Duffee, Wis. Cir. 299; Stefaniak, Rupel, Bohstedt, and Peterson, Wis., Jour. Dairy Sci., 30, 1947, pp. 103–114; Wyo. Rpt. 57; Woodward and Shepherd, U.S.D.A. Tech. Bul. 611; Graves et al., U.S.D.A. Tech. Bul. 649; Shepherd et al., U.S.D.A. Tech. Bul. 1079; Logan, Canada, Jour. Dairy Sci., 37, 1954, pp. 247–251.
24. Montavon, Ill., Jour. Dairy Sci., 37, 1954, pp. 905–909.
25. Morrison and Deal, Ga., Jour. Dairy Sci., 35, 1952, p. 501.
26. Connell, Washburn, and Wheeler, Colo. Farm. Bul. 8, 1946, No. 8; Klosterman, Bentley, and Moxon, Ohio Anim. Sci. Mimeo. Ser. 79; Ziegler, Bentley, and Miller, Penn. Bul. 410; Hobbs and Hoyt, S.D. Rpt. 1947; see also: Ill. Rpt. 1938–47; Beeson, Perry, Nickel, and McVey, Ind., mimeo. rpt., Garrigus, Ky. Bul. 579.
27. Klosterman, Kunkle, and Rogers, Ohio Anim. Sci. Mimeo. Ser. 94.
28. Branaman and Davis, Mich. Quar. Buls. 22, 1939, No. 1; 23, 1940, No. 2; 25, 1942, No. 1; see also: Ark. Bul. 428; Trowbridge, Dyer, and Comfort, Mo. Bul. 477.
29. Miller and Brannon, N.Y., mimeo. rpt.; Livesay and Cunningham, West Va. Bul. 363, Part 1.
30. Cunningham and Livesay, West Va. Bul. 369, Part 1.
31. Cox and Smith, Kan. Cir. 283; Duitsman and Kessler, Kan. Cir. 307; Cathcart et al., Kan. Cir. 308; Mo. Bul. 510; Dowe, Matsushima, and Arthaud, Nebr. Cattle Progress Rpt. 213.
32. Miller, Ferguson, and Brannon, N.Y., mimeo. rpt.
33. Garrigus, Ky. Exten. Cir. 361, Ky. Rpts. 1940, 1942, 1943, 1944, 1945, 1953; Blakeslee, Henneman, and Nelson, Mich. Quar. Bul., 37, 1954, No. 1; Bell, Ohio Bul. 659, and mimeo. rpts.; see also: Esplin and Connell, Colo. Farm Bul., 8, 1946, No. 2; Welch, Livesay, and Lewis, West Va. Bul. 363, Part 4.
34. Jordan, S.D. Cir. 106.
35. Neale and Bell, New Mex. Bul. 309; see also: Jones and Bayles, Tex. Rpt. 1940.
36. Terrill, Becker, Edwards, and Nesheim, Ill.,

Jour. Anim. Sci., 12, 1953, pp. 941–942.
37. Winters, Minn., Country Gentlemen, Nov. 1952.
38. Experiments summarized by Heuser, Feeding Poultry, 2nd Ed., 1955, pp. 244–246.
39. Atkeson et al., Kan. Rpt. 1942–44; Krauss, Hayden, Perkins, and Washburn, Ohio Bimo. Bul. 192.
40. Shepherd, Gordon, Wiseman, and Melin, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 1190–1200.
41. Peterson, Thoma, and Anderson, Wis. Bul. 496.
42. Shepherd and Woodward, U.S.D.A. Cir. 603; Otis, Minn. Farm and Home Sci., 4, 1947, No. 3; Eckles, Reed, and Fitch, Mo. Bul. 164 and Kan. Cir. 89; Chase, Nebr. Cir. 1; King, Wis. Bul. 59.

CHAPTER XVI

LEGUMES FOR FORAGE

I. Superiority of Legume Forage

449. Advantages of legume forage. —Legume roughages occupy a place of particular importance in the feeding of livestock, because of the several superiorities they have over all other forage crops. They excel in the following respects:

1. They lead in yield of palatable hay per acre. In nearly every livestock section of the United States some kind of legume will produce a greater yield per acre than other common hay crops. Moreover, this hay is so much more palatable than grass hay of the usual quality, that stock will eat larger amounts of it and thus get a larger part of their nourishment from this cheap source.

2. They are the richest in protein of all common forages. Therefore their use greatly reduces the amount of protein supplement needed to balance a ration. Indeed, merely good legume hay and farm grain make a well-balanced ration for some classes of stock.

3. Their protein helps correct the deficiencies in the proteins of the cereal grains. This is well shown by the fact that pigs fed only corn on alfalfa pasture will make fairly satisfactory gains, though they will do still better when a small amount of high-quality protein supplement is fed in addition.

For dairy cows, beef cattle, sheep, and horses, protein of entirely satisfactory quality is always assured whenever good legume forage forms any considerable part of the roughage.

4. Legume forages are the highest in calcium among all farm-grown feeds. If dairy cattle, beef cattle, sheep, or horses get plenty of good legume forage, there is no need to add a calcium supplement to the ration.

Legume roughages are not rich in phosphorus, containing less than do the cereal grains. However, their phosphorus content is generally a little higher than that of forage from corn, the sorghums, or the grasses.

5. Legume forage excels in vitamin A value. It has been pointed out in Chapter VII that well-cured legume hay has much more carotene, and consequently is much higher in vitamin A value, than is hay from the grasses or other dry forage. Legume silage is even richer in vitamin A value. During the barn-feeding season stock will generally have an abundance of vitamin A if good legume or mixed legume-grass hay or silage forms a considerable part of their roughage.

6. Field-cured legume hay is rich in vitamin D. Good-quality, field-cured legume hay is the richest source of vitamin D among common feeds. Dairy cows, beef cattle, sheep, and horses will be plentifully supplied with this vitamin when fed a reasonable amount of such hay, or of good field-cured mixed legume-and-grass hay. Only 5 per cent of field-cured legume hay in the ration will generally furnish enough vitamin D for pigs in winter.

7. Legume forage is rich in other vitamins. Plenty of good legume hay will usually supply ample amounts of the other vitamins needed by livestock, except in the case of poultry, which have especially high requirements for riboflavin and certain other B-complex vitamins.

8. Legumes increase the yield and protein content of grasses. Such legumes as alfalfa and the clovers increase the yield and protein content of the grasses when grown in combination with them. For pasture or for hay, a combination of grasses and legumes is therefore usu-

ally far preferable to any mixture of grasses alone, without legumes.

In Ohio experiments over several years a combination of timothy with red clover, alsike clover, or alfalfa yielded over 40 per cent more hay than timothy alone. Also, the percentage of protein in timothy or orchard grass (not including the legumes) was 44 to 50 per cent higher when grown with alfalfa than when the grass was grown alone.[1]

This beneficial effect of legumes upon the composition of grasses is probably due, at least in most part, to the nitrogen furnished to the soil when the nitrogen-bearing nodules on the legume roots are shed and decay.

9. *Legumes are highly important in maintaining soil fertility*. Through the action of the legume bacteria in the nodules on their roots, legumes use in their growth free nitrogen gas from the air. It must be kept in mind that they build up the nitrogen content of the soil only when the proper nodule-forming bacteria are present. Where these are lacking, it is essential that the soil be inoculated.

The legume bacteria are so effective in using nitrogen from the air that the nitrogen content of the soil may be increased even when such a legume hay crop as alfalfa or red clover is grown and all the hay removed, only the stubble and roots being returned to the soil.[2] On the other hand, when soybeans, which have a much less extensive root system, are grown for hay, without returning the manure, there may be a slight loss of nitrogen from the soil.

Not only do legume crops aid in maintaining the nitrogen supply in the soil, but also they increase the yield of succeeding crops by rendering the soil nitrogen more active and available and by producing other benefits. Thus, deep-rooted legumes, such as alfalfa and sweet clover, penetrate and open up soil layers below the plow line. The roots furnish organic matter to keep the soil particles aggregated and porous, thus improving soil structure.

The beneficial effects do not continue for many years after the growth of the legume crop. It is therefore advantageous from this standpoint, as well as for the maintenance of the nitrogen supply of the soil, to grow the legumes chiefly in regular crop rotations, instead of growing such a crop as alfalfa for a long time on the same field.

II. Alfalfa

450. Importance of alfalfa.—Over one-third of all the tame hay produced in the United States is now alfalfa (*Medicago sativa*). Alfalfa has come to occupy this leading position because it out-yields other hay crops and also because of its palatability, its richness in protein, and its high content of calcium and of vitamins. In addition to the importance of alfalfa for hay, alfalfa and alfalfa-grass mixtures are widely used for pasture and for silage. Because of the excellence of alfalfa hay and other alfalfa forage, they are commonly taken as the standards with which other forage crops are compared.

While alfalfa was at first raised chiefly in the western states, it is now grown in most areas of the United States where the soil is well-drained and not so acid as to make the cost of liming prohibitive. The North Central States now lead in acreage of alfalfa, though California is first in tonnage of alfalfa hay, because of the high yields secured under irrigation.

The reasons for the popularity of alfalfa hay are shown in the following table. This shows the average yield of nutrients per acre throughout the United States from alfalfa hay, from clover-and-timothy hay, and from corn silage.

Average yields of nutrients from alfalfa hay and other crops

	Yield per acre	Dry matter	Digestible protein	Total digestible nutrients
	Tons	Lbs.	Lbs.	Lbs.
Alfalfa hay	2.20	3,982	453	2,231
Clover-and-timothy-hay	1.41	2,484	132	1,438
Corn for silage	8.00	4,416	192	2,928

This table, computed from the average yields for the whole country, shows that alfalfa produces a much larger yield of hay and of dry matter

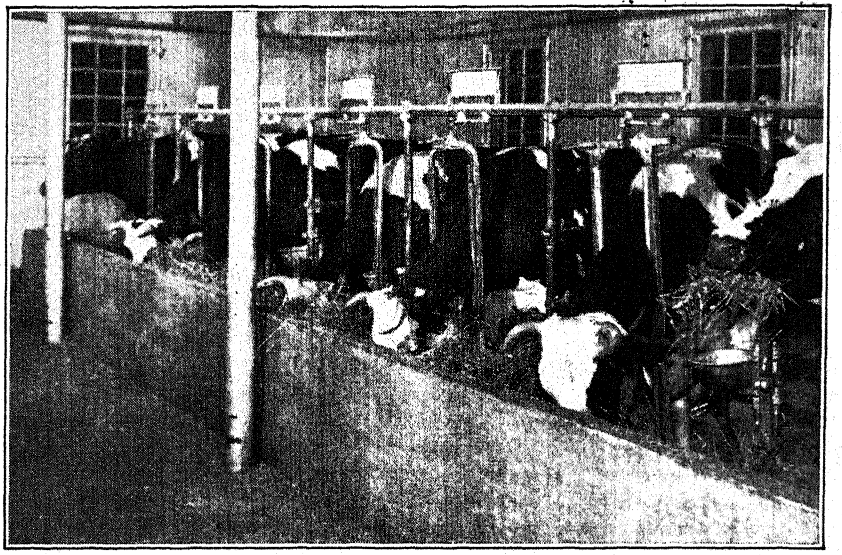
per acre than does clover and timothy. It is slightly excelled in yield of dry matter by corn grown for silage.

Alfalfa hay provides over three times as much digestible protein per acre as clover-and-timothy hay and 2.4 times as much as corn grown for silage. It furnishes much more total digestible nutrients per acre than does clover-and-timothy hay, and is excelled only by corn silage. In addition, alfalfa hay is much richer in calcium and also higher in carotene and other vitamins than are these other crops.

Considerably larger yields of alfalfa hay are secured under favorable conditions than shown in the table. Even in the eastern states, yields of 3 to 4 tons per acre during the season are not uncommon. In the West very heavy yields are often secured under irrigation. In the hot irrigated districts of the Southwest, 8 or even more cuttings are sometimes made in a year. Where both soil and climate are suitable, alfalfa returns good crops for many years without reseeding. When high temperature is combined with a humid climate, alfalfa generally fails unless the soil is unusually favorable.

Because alfalfa sends its roots deep into the subsoil on well-drained land, it is able to draw moisture from a great depth of soil. In a semi-arid climate this may bring about a decided depletion in the moisture of the subsoil, for the alfalfa can draw upon water which has been stored there over a long period. This depletion of subsoil moisture is one of the chief reasons why alfalfa often fails to thrive in such dry districts when seeded on land which has been in alfalfa several years. The very efficiency of the crop in obtaining water thus proves its undoing on that particular field. This probably has been the chief cause of the decrease in alfalfa acreage in certain western states during recent years.

Where alfalfa thrives best, it will produce a larger yield when seeded alone than when sown with a grass. In other areas, as is pointed out later in this chapter, the stand lasts longer and



LEGUME HAY IS UNEXCELLED AS ROUGHAGE

Legume hay and other legume forages are unexcelled, because of their several superiorities over other forages. Dairymen are fortunate who have an abundance of well-cured legume hay for their cows.

a larger yield is secured over a period of years when alfalfa is seeded in combination with a suitable grass, such as timothy or bromegrass. (469)

451. Varieties and types of alfalfa.—The *variegated alfalfas* are of much importance in the northernmost states and in Canada, as they are much more winter-hardy than common alfalfa. These varieties, which have various-colored and variegated blossoms, are hybrids between ordinary alfalfa and the yellow-flowered or Siberian alfalfa (*Medicago falcata*). To this class belong the well-known Grimm, Cossack, Ontario-Variegated, Baltic, Ladak, Hardigan, Ranger, Atlantic, and Narragansett varieties, and the new Vernal alfalfa.

Turkestan alfalfa is indistinguishable from common alfalfa in growth. It is somewhat hardier but usually yields less hay. *Peruvian alfalfa* is a rapidly-growing, non-hardy type, which is particularly well adapted to the southernmost alfalfa districts. Recently, creeping or pasture-type alfalfas have been produced, which spread by underground rootstalks and persist longer in pastures.

Varieties, such as Ranger, Buffalo, and Vernal, have been developed which are very resistant to bacterial wilt disease, and other varieties have been produced for certain areas, which are resistant to other diseases or to nematodes.

Which is the best variety for any area will depend entirely on the local conditions. Any person in doubt as to the variety to use should secure advice from his state experiment station, agricultural college, or county agent. The value of any variety will depend primarily on how it thrives in a given locality and on its yield. The value per ton of the forage from different varieties does not differ appreciably, so far as is known.

LEGUMES CAN USE NITROGEN OF AIR ONLY WHEN INOCULATED

When the nitrogen-fixing bacteria or germs are lacking, it is essential that the soil be inoculated to secure maximum crops. At left, are soybeans on sandy soil which were inoculated with the proper bacteria; at right, soybeans which were not inoculated. (From Wisconsin Station.)

452. Composition and value of alfalfa hay.—Alfalfa hay possesses to a high degree the nutritive advantages common to legume forages, which have been emphasized earlier in this chapter. (449) It has an average of 15.3 per cent protein, in comparison with 12.0 per cent for red clover, and the protein in alfalfa is more digestible. As a result, average alfalfa hay furnishes 10.9 lbs. digestible protein per 100 lbs., against 7.2 lbs. for clover.

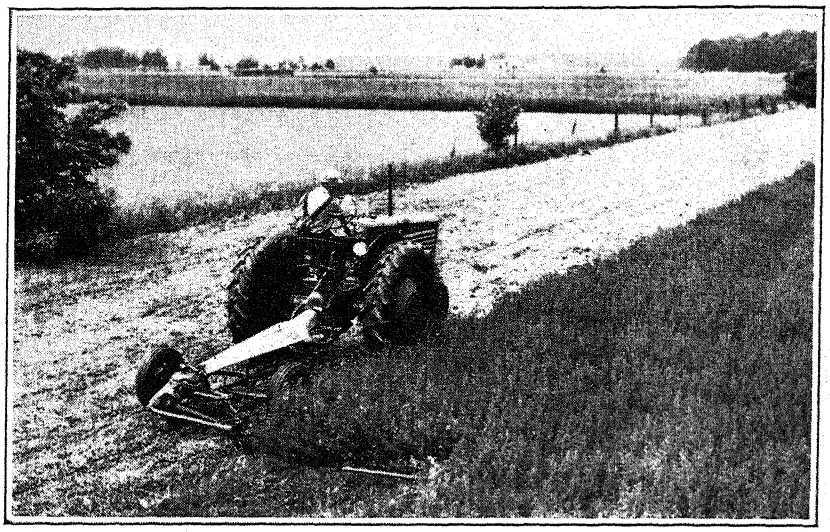
There is therefore a decided differ-

ence in the amount of protein supplement needed to balance a ration when stock are fed alfalfa hay in place of clover hay. Indeed, a supplement may not be required with alfalfa, while it may be needed with clover. The protein content of alfalfa hay varies considerably, even in hay harvested at the same stage of maturity and well cured. Occasionally it will contain no more protein than clover hay.

The fact that the protein of alfalfa helps to correct the deficiencies of the proteins of the cereal grains has been pointed out previously. (**126**)

Alfalfa hay supplies practically as much total digestible nutrients as does red clover hay, and is appreciably higher than timothy hay. In actual feeding experiments with dairy cows, beef cattle, and sheep alfalfa hay has always been equal or even superior to hay from the grasses in productive value, even when the lack of protein in grass hay was corrected by adding protein supplement.

However, in certain net energy investigations alfalfa hay has had a slightly lower net energy value than clover hay and a decidedly lower value than timothy hay.[3] This lower net energy value of alfalfa hay apparently results from a stimulating effect on body metabolism and heat production, perhaps caused by hormones present in alfalfa. (**54**) This stimulating effect on metabolism produced by hay from alfalfa and other legumes (which stimulation reduces its net energy value) is probably one of the reasons why such excellent production is secured when dairy cows and other stock are fed plenty of good legume hay.



ALFALFA IS OUR MOST IMPORTANT HAY CROP

A fine field of alfalfa. Because of the merits of alfalfa for hay, it has become the most important hay crop in the United States.

Because good alfalfa hay has been proven to be fully equal to first-class timothy hay in productive value in the practical feeding of livestock, the author has rated average alfalfa hay equal to excellent timothy hay in the estimated net energy values given in Appendix Table II.

Alfalfa hay is exceptionally rich in calcium, having an average of 1.47 per cent. This high calcium content is of especial importance for dairy cows, breeding stock, and young growing animals. Alfalfa hay has only a fair phosphorus content, averaging 0.24 per cent.

On phosphorus-deficient soils, it may be very low in phosphorus content.

Alfalfa hay of good quality has a high vitamin A value, because of its richness in carotene. For this reason, alfalfa meal, especially dehydrated alfalfa, is widely used to supply carotene and other vitamins in rations for poultry and swine. As has been shown earlier, the carotene content will vary widely, depending on the stage of maturity at which the hay was cut, on how well it was cured, and on how much carotene has been lost during storage. (**195–196**) Generally, leafy hay which has considerable green color will be good to high in carotene content.

Field-cured alfalfa hay is a good source of vitamin D for all stock except poultry. The form of vitamin D in alfalfa and other field-cured hays is not well utilized by poultry. Also, their requirements for the vitamin are so high that they need special vitamin D supplements, even when alfalfa products are included in their rations.

Good alfalfa hay is quite rich in riboflavin and in niacin. In addition, it has other vitamins that may be lacking in rations for animals which get no fresh green feed. (**222**)

Alfalfa is also a good source of vitamin K. (**225**) Even 1 to 2 per cent of good-quality alfalfa meal in the ration usually furnishes sufficient of this vitamin for poultry.

In this country, where yellow skin is preferred in market poultry, the xanthophyll in alfalfa meal helps to produce it. (**14**)

453. Differences in composition and value of alfalfa hay.—Alfalfa hay like all other kinds of hay, varies widely in value, depending, first of all, on how it was cured. (Chapter XIV) Hay of a good green color, cured without rain and with little shattering of leaves, has the highest feeding value. Since the leaves contain twice as high a percentage of protein as the stems, a considerable loss of leaves in hay-making not only decreases the yield of hay but also decidedly lowers the value per ton. Except from the vitamin standpoint, hay which is of good quality but not bright green in color may be about as valuable as green-colored hay, if it is as leafy and has not been leached by rain.

With hay cured equally well, the chief factor affecting the composition is the stage of maturity at which it is cut. The earlier the hay is cut, the higher it will be in protein and vitamins, the lower it will be in fiber, and the greater will be the digestibility. (Appendix Table I.) In general, alfalfa hay cut reasonably early (when from one-tenth to one-half in bloom) is best for dairy cows, beef cattle, sheep, and swine. That cut very early is preferred for poultry and rabbits. Hay cut in full bloom is best for horses, as early-cut hay may be too laxative. Hay cut too early may also cause scours in young calves.

When alfalfa hay is fed to dairy cows in the usual rations, along with a reasonable allowance of concentrates, there is not apparently much difference in the value per ton of hay cut extremely early and that cut in early bloom. For example, in extensive Arizona tests, there was no difference in the milk or fat production when cows were fed alfalfa hay cut at the bud stage in comparison with hay cut when one-third in bloom.[4] The bud-stage hay was slightly more palatable, and the cows ate a little more of it. To offset this, a trifle more of the concentrate mixture was fed with the one-third-bloom hay.

When alfalfa hay is fed to dairy cows as the only feed, as is sometimes done in certain sections of the West, hay cut very early will have an appreciably higher value than later-cut hay. In 3 Montana trials the milk production was 14 per cent higher when cows were thus fed alfalfa hay cut at the beginning of bloom, than when they were fed hay cut at the half-bloom stage.[5] The milk yield on hay cut at full bloom was 8 per cent below the yield on the hay cut at half bloom. Similarly, in Kansas tests beef steers fed only alfalfa hay cut at the bud stage made 18 per cent more gain per ton of hay than when fed hay cut when one-tenth in bloom.[6]

After the full-bloom stage, the value

of alfalfa hay falls decidedly. Such late-cut hay is less palatable and considerably lower in digestible nutrients. In the Kansas tests with beef steers, hay cut when one-tenth in bloom produced twice as much gain per ton as hay cut in the seed stage.

In trials by the United States Department of Agriculture dairy heifers were fed U.S. No. 1 or 2 alfalfa hay, containing 26 to 30 per cent fiber, as the sole ration, in comparison with poor alfalfa having 37 to 38 per cent fiber.[7] The heifers fed the good hay gained 28 per cent more and required 12 per cent less hay per pound of gain.

The relative value of the different cuttings of alfalfa hay will depend on climatic conditions. In the corn belt and eastward the first cutting is commonly coarser and less leafy than the later cuttings and therefore is of somewhat lower value, when the different cuttings are equally well cured. Also, the weather is often less favorable for curing the first crop. On the other hand, in some of the western irrigated districts, the first cutting is more leafy and finer stemmed than some of the later cuttings.

In general, fine-stemmed, leafy hay is worth more than coarser, stemmier hay. The difference in value is greatest for poultry, swine, and sheep, and is less for dairy cows or beef cattle which are fed concentrates in addition to the hay. In many districts there is a decided prejudice among stockmen in favor of a certain cutting of alfalfa hay, though the actual difference in value of the various cuttings may be much less than the difference in market price.[8]

Alfalfa hay badly damaged by rain, stemmy hay that has lost most of the leaves, or hay otherwise of poor quality has a much lower value than hay of good quality.[9] Stock will eat much less of such poor hay, and the nutritive value per pound is decidedly less.

Occasionally, cattle or sheep fed leafy, good-quality alfalfa hay as the only roughage tend to bloat. Such trouble may usually be prevented by feeding some non-legume roughage, such as corn or sorghum silage, along with the alfalfa.

The use of alfalfa straw or chaff is discussed later. (513)

454. Stage to cut alfalfa.—In deciding when to cut alfalfa for hay, one must consider not only the quality of the hay but also the effect upon the length of life of the stand. Extensive experiments have shown that, except perhaps where the conditions are most favorable to alfalfa, repeated cutting of a field before early bloom will weaken the plants and shorten their life. This is due to a depletion of reserve food in the alfalfa roots, brought about by the early and frequent cutting. These reserves are built up in the roots during the blossoming period and later.

Cutting a vigorous stand occasionally as early as the bud stage will not usually produce any noticeable injury, but the same field should not be cut early repeatedly. The same area should not be cut first each year, and it is wise to delay cutting of a new seeding until after the older stands have been cut.

In the humid districts, the first growth of alfalfa in the spring is generally coarser and stemmier than later cuttings. Cutting such rank growth reasonably early makes much better-quality hay than if it is cut when in full bloom. When leafhopper infestation is severe, cutting the crop at a particular time may aid in preventing damage. If alfalfa has been injured by severe winter weather, cutting it at the full-bloom stage the following spring will aid it to recover.

Where the winters are severe, the stand is maintained better if the alfalfa is not cut for hay in the fall or grazed closely, but a growth 6 inches or more in height is left for winter protection. When it is desired to cut alfalfa or to graze it in the fall, the stand is injured less if this is delayed until late October, by which time the fall growth will have been made and the storage of nutrients in the roots will have taken place.

Since the best practice will differ considerably in the various sections of the country, any person in doubt as to the best time to cut the crop should consult his agricultural college, experiment station, or county agent.

455. Alfalfa meal; alfalfa pellets.—More than one million tons a year of alfalfa meal are now produced commercially in this country for use in livestock rations, chiefly as a vitamin supplement. Except in certain western alfalfa districts where the climate is especially favorable for making high-quality field-cured hay, the alfalfa is dehydrated for this purpose.

Alfalfa meal is commonly used as a vitamin supplement in commercial poultry mashes, and it is also widely used to furnish vitamin A in formula feeds (commercial mixed feeds) for swine, dairy calves, and such animals as rabbits. It is likewise a common ingredient in formula horse and mule feeds.

The use of alfalfa meal and of alfalfa hay as a vitamin supplement for the various classes of stock is discussed in Part III. Information is given concerning the nutritive and feeding value of dehydrated hay in general in Chapter XIV. (**416–420**)

Alfalfa meal is the product obtained by grinding entire alfalfa hay without the addition of any alfalfa stems, alfalfa straw, or foreign material, or the removal of any of the leafy portion. It should be made from leafy hay of good quality, and the fiber content should not be higher than about 29 to 30 per cent, for the average fiber content of alfalfa hay is only 28.6 per cent. A higher percentage of fiber shows that the meal has been made from hay of poorer quality. According to the definitions of the Association of American Feed Control officials, alfalfa meal must not have more than 33 per cent fiber.[10]

It is often impossible to determine without chemical or laboratory analysis whether alfalfa meal has been made from leafy, early-cut hay or from over-ripe, stemmy material. Hence the meal should be purchased on guarantee of composition.

Dehydrated alfalfa meal is usually fully twice as high in carotene as the products made from field-cured hay, and it is also somewhat higher in riboflavin. However, it has practically no vitamin D, while alfalfa meal from field-cured hay has considerable. This lack of vitamin D in the dehydrated product is not of importance in feeding poultry, for the reasons pointed out earlier in this chapter. However, in using the dehydrated products as a vitamin supplement for swine, it must be borne in mind that they do not supply vitamin D, like field-cured hay does.

The carotene content of various lots of alfalfa meal, even dehydrated alfalfa, unfortunately varies widely. Therefore, in the use of these feeds as vitamin A supplements in making formula feeds, the manufacturer should use products of known carotene content. Otherwise, he cannot be sure that his feeds will actually have the desired vitamin A value.

The losses of carotene and vitamin A in feed during storage and methods of greatly reducing the losses have been discussed in Chapter VII. (**195**)

If one has no legume hay available for feeding to his stock, the purchase of alfalfa meal as a substitute may be warranted, but most farmers can grow good legume hay much more cheaply than they can buy alfalfa meal. It must be borne in mind that fine grinding does not change a roughage into a concentrate, nor does it increase its digestibility for animals with good teeth. Any advantage from grinding or chopping hay probably results from a saving in wastage or in getting animals to eat more than they would otherwise consume. The effect of grinding or chopping hay for the various classes of stock is discussed in Chapter IV.

456. Alfalfa leaf meal.—Alfalfa leaf meal, according to the definition of the Association of American Feed Control Officials, is the ground product consisting chiefly of alfalfa leaves. It must be reasonably free from other crop plants, weeds, and mold, and must have at least 20 per cent protein and not more than 18 per cent fiber.[10]

Some years ago considerable alfalfa leaf meal was produced by screening the coarser stemmy portion from alfalfa meal after it was ground. Now there is but little alfalfa leaf meal on the market, and apparently the name is sometimes used

for the entire ground hay when it is cut so early and is of such high quality that it is low in fiber. However, some of the product sold as alfalfa leaf meal exceeds the limit of 18 per cent fiber, as will be noted in Appendix Table I.

457. Alfalfa stem meal.—Alfalfa stem meal is the product screened from ground alfalfa hay when alfalfa leaf meal is made in this manner. It is much lower in protein and higher in fiber than good alfalfa hay, and has a correspondingly lower feeding value. When very finely ground, it may be difficult to distinguish alfalfa stem meal from alfalfa meal, without laboratory examination.

458. Alfalfa hay for dairy cattle.—Good alfalfa hay is unexcelled as a dry roughage for dairy cattle and may be taken as the standard with which other kinds of hay are compared. If good cows have an abundance of well-cured alfalfa hay as part of a balanced ration, they will produce a high yield of milk and will need less grain and other concentrates than when less palatable and efficient roughage is fed. This results in a considerable saving in the cost of milk production.

Often dairymen who are feeding an abundance of good alfalfa hay to their cows use concentrate or grain mixtures which are much higher in protein than actually needed. If the protein-rich mixture costs more than one lower in protein content, such a practice is decidedly uneconomical. It is shown in Chapter XXV that for cows of any usual productive capacity there is no need to add a protein supplement to a ration consisting of corn or other grain plus an abundance of good alfalfa hay, fed as the only roughage. (**1017**)

It is wise to add a phosphorus supplement to a ration consisting of only grain and alfalfa hay (with or without corn or sorghum silage, but without any protein supplement) unless the roughage has been grown on soil rich in phosphorus. (**1035**)

The great differences in feeding value between good and poor hay and between early-cut and late-cut hay have been emphasized in Chapter XIII and in Chapter XIV. (**358, 391–392**)

In some sections of the West alfalfa hay is so much cheaper than other feeds that dairy cows are fed only alfalfa hay during the winter and sometimes even throughout the year. Such a ration is too bulky and low in digestible nutrients for high production and is also very high in protein. Breeding troubles have been attributed to this ration, but experiments have shown that the excess of alfalfa hay and of protein is not responsible for such troubles. Instead, they are commonly due to brucellosis (Bang's disease).

Whether or not it will be most economical to feed only alfalfa hay to good cows in such districts, will depend on the relative price of alfalfa and other feeds and also on the price of milk. (**1028**) Adding corn or sorghum silage to the ration may sometimes be more profitable than adding grain.

The opinion is sometimes stated that alfalfa hay is too laxative for young calves. However, New York and Wisconsin experiments, as well as the experience on innumerable farms, show that alfalfa hay is very satisfactory for dairy calves, right from the start of hay feeding.[11]

If cows are fed alfalfa hay as the only roughage throughout the entire year, without any pasture or other green feed, they may tire of the alfalfa. They will then produce decidedly better results when fed some other roughage in addition, even grass hay of ordinary quality.

Alfalfa hay should be fed after milking, instead of before milking. This is because the flavor of the milk may be injured if alfalfa hay is fed less than about 4 hours before milking time. When cows are fed nothing but alfalfa hay, the butter may be undesirably hard. This condition can be corrected by adding silage to the ration.

459. Alfalfa meal; alfalfa pellets; chopped alfalfa hay for dairy cows.—Alfalfa hay of good quality is eaten by dairy cows with so little waste that it does not pay to go to additional expense to chop it for them. When field-chopped hay is made, it should be chopped as

long as possible. (407) It is shown in Chapter XXV that finely ground hay or alfalfa pellets as the only or the chief roughage for dairy cows is decidedly undesirable. (1052)

When dairy cows receive a ration that includes plenty of legume hay or even good mixed hay, there is no special advantage in adding alfalfa meal, even dehydrated alfalfa, to the concentrate mixture. Alfalfa meal, or ground alfalfa hay, even when made from hay of first-rate quality, is distinctly a roughage and not a concentrate. Average alfalfa meal contains over twice as much fiber as wheat bran and supplies much less total digestible nutrients. It cannot therefore replace any large part of the concentrates needed for high milk production.

In experiments where alfalfa meal has been compared with bran in good rations, the bran has generally had a decidedly higher value per ton.[12] In Kentucky trials in which alfalfa meal was substituted for 23 to 37 per cent of a usual concentrate mixture, the added alfalfa meal was worth about two-thirds as much per pound as the ordinary concentrate mixture.[13] Similar results were secured in Wyoming experiments in which dehydrated alfalfa pellets or meal replaced 20 per cent of the usual concentrate mixture.[14]

If the total amount of feed eaten by cows is increased by *adding* alfalfa pellets or alfalfa meal to a good ration, the milk production will of course be increased somewhat.[15] At the usual price of alfalfa meal or pellets, it might be appreciably more economical to feed a correspondingly greater amount of the ordinary concentrate mixture.

In 3 Oklahoma experiments with prairie hay as the only roughage, 30 per cent of the usual concentrate mixture was replaced with alfalfa meal made from leafy alfalfa and 10 per cent more of this mixture was fed, because of the lower digestible nutrient content of alfalfa meal.[16] The feeding of the alfalfa meal did not increase milk production, and each 100 lbs. of alfalfa meal was worth about as much as 65 lbs. of concentrates.

460. Alfalfa hay for beef cattle.—Alfalfa hay has no superior for feeding beef cattle. Not only is it an excellent roughage for fattening cattle, but also its value for the breeding herd is perhaps even more outstanding. When any reasonable proportion of the roughage consists of well-cured alfalfa hay, one can be sure that there will be no deficiency in quality of protein or in calcium or vitamins.

It is shown in Chapter XXVIII that if fattening cattle are fed a liberal amount of alfalfa hay as the only roughage with corn or other grain, it generally does not pay to add a protein-rich concentrate, such as cottonseed or linseed meal. However, when the cattle are fed corn or sorghum silage in addition to alfalfa hay, this succulent feed is so palatable that they will not eat enough alfalfa to balance the ration completely. To secure the best results, it is then necessary to add a small amount of a protein supplement.

Alfalfa hay may be used as a protein supplement to low-protein roughage, such as corn or sorghum silage, in wintering young beef cattle or breeding cows. However, it will take about 3 lbs. of alfalfa hay to replace 1 lb. of cottonseed meal or soybean oil meal for this purpose, because of the much lower protein content of the hay. (See Chapter XXIX.)

The chopping or grinding of alfalfa hay for beef cattle and the fattening of cattle on alfalfa hay alone, or on alfalfa hay and other roughage, are discussed in Chapter XXVIII.

461. Alfalfa hay for sheep.—Alfalfa hay is such a good feed for sheep that it may be taken as the standard with which other roughages are compared. For sheep feeding, hay that is leafy and fine stemmed should be used, if possible, as it is of decidedly higher value than coarse, stemmy hay. In New Mexico tests, fine leafy alfalfa was worth 39 per cent more per ton than coarser-stemmed hay for fattening lambs when the hay was fed as the only roughage, and 8 to 27 per cent more when sorghum silage was fed in addition.[17]

Lambs cannot be fattened sufficiently for the large markets on alfalfa hay alone, even of the best quality. If it is desired to fatten lambs for marketing late in the winter or in the spring, it may be desirable to feed them hay alone during the first part of the fattening period and later to add grain to the ration.

There may be a greater tendency for the stiff-lamb disease to occur when ewes are fed alfalfa hay as the only roughage in winter, than when other roughages are also fed.

462. Alfalfa hay for horses and mules.—Experience on thousands of farms in the western part of the United States, where alfalfa hay has been used for many years as the only roughage for horses and mules, shows that it is economical and entirely satisfactory when properly fed.

Alfalfa hay for horses should be free from dust or mold and should not be cut until about full bloom, as hay cut earlier may be too laxative. Alfalfa is very palatable to horses, and therefore the amount must be strictly limited, or they will eat too much. Not over 1.0 to 1.1 lbs. daily per 100 lbs. of live weight should be fed work stock. Although alfalfa hay can be fed with entire success as the only roughage, some prefer to use it for but one-third to one-half the daily allowance of hay, the remainder being hay from the grasses.

Several experiments have shown that alfalfa hay is excellent as the only roughage for horses or mules at hard work.[18] When alfalfa is the roughage, less grain is needed to keep them in condition than with average timothy or other grass hay.

A common ration for idle horses in the West is alfalfa hay fed with no grain, but often with what straw the animals will eat.

463. Alfalfa hay, alfalfa meal for swine.—For swine not on pasture, good-quality alfalfa hay and other legume hay is of especial value as a vitamin supplement. The legume hay not only furnishes vitamin A value and vitamin D in addition (if it is field-cured), but it also supplies other vitamins which may be lacking when swine are confined in dry lot, with no green feed.

Such a ration as yellow corn and soybean oil meal, plus minerals, is unsatisfactory for continuous feeding over a long time to brood sows or young pigs in dry lot, because of deficiencies in vitamins. By including a sufficient amount of good alfalfa hay in the ration, these deficiencies are largely corrected and fairly good results are usually secured.

Even such a ration as corn and tankage is decidedly improved for young pigs not on pasture by the addition of alfalfa hay or other legume hay. In 8 experiments 62-lb. pigs fed yellow corn and tankage in dry lot until they were ready for market gained an average of 1.16 lbs. per head daily.[19] The addition of 4 per cent of alfalfa hay to the ration increased the gain to 1.26 lbs. and also reduced the amount of feed required per 100 lbs. gain. In these experiments each 100 lbs. of alfalfa hay saved 112 lbs. corn plus 31 lbs. tankage, without giving it any credit for the increase in rate of gain. This shows how well it pays to provide legume hay for pigs fed such a ration as corn and tankage in dry lot.

If any other grain than yellow corn had been fed in these experiments, the addition of alfalfa hay would have been even more beneficial, for many of the pigs fed grain and tankage, without alfalfa hay, would have been injured by the deficiency of vitamin A. Also, if the pigs had been started on the trials immediately after weaning, those fed yellow corn and tankage would not have made as creditable gains as were made by these 62-lb. pigs. The younger the pigs are when they are put in dry lot without green feed, the greater will be the advantage in supplying them with good legume hay.

The use of legume hay or alfalfa meal as a vitamin supplement in swine feeding is more fully discussed in Chapter XXXIV. Even such a ration as corn, tankage, and alfalfa hay is not quite ideal for young pigs in dry lot. Still better results will be secured by using one of the supplemental mixtures there recommended.

Alfalfa stem meal or poor quality alfalfa meal should not be used to protect swine in dry lot against vitamin deficiencies, because of the low vitamin content.

464. Alfalfa hay as the only supplement to grain for swine.—Alfalfa hay is fairly rich in protein, and the protein is also of such quality that it helps to correct the deficiencies in the proteins of the grains. The question therefore arises as to whether alfalfa hay is satisfactory when used as the only protein supplement to the grains in swine feeding. A ration consisting only of legume hay and grain is satisfactory for wintering pregnant sows a year of age or more, if the hay is of excellent quality. For younger sows during pregnancy and also for all sows when they are suckling their pigs, a small amount of a more concentrated protein supplement should be added to the ration.

Growing and fattening pigs have less capacity to consume hay than have older swine. Also, their needs for protein are relatively large. While the addition of alfalfa hay to a full feed of corn for pigs will produce decidedly better results than corn alone, the gains are much less rapid and also less economical than when a more concentrated and more efficient protein supplement is fed in addition.

For example, in 14 experiments well-grown pigs, averaging 102 lbs. in weight at the start, gained but 1.08 lbs. per head daily on a full feed of corn supplemented by only alfalfa hay.[20] Others fed corn and tankage, with no alfalfa hay, gained 1.51 lbs. a day and required considerably less feed per 100 lbs. gain. In these trials each 100 lbs. of tankage replaced 194 lbs. corn plus 174 lbs. of hay, without considering the large increase in rate of gain.

Still better results would have been secured with these pigs, fed in dry lot, if alfalfa hay had been added to the ration of corn and tankage. Also, if the pigs fed only corn and alfalfa hay had not been well-grown when placed on this ration the results would not have been nearly so good as were secured in these tests.[21] Young pigs need very much more protein than is provided by a ration consisting only of corn and excellent alfalfa hay.

Alfalfa hay produces somewhat better results when fed as the only protein supplement to other grains that are higher than corn in protein. However, unless efficient protein supplements are unusually high in price, it is usually economical to add such a supplement to a ration of alfalfa hay and a full feed of barley, wheat, oats, kafir, or rye, especially for pigs under 100 to 125 lbs. in weight.[22]

465. Alfalfa meal, alfalfa hay for poultry.—Alfalfa meal is used extensively as a vitamin supplement in poultry rations. Not only does alfalfa meal supply carotene, which furnishes vitamin A, but it also helps provide riboflavin and other B-complex vitamins, including one of the unidentified vitamins. (222) In addition, alfalfa supplies vitamin K, which in poultry is necessary to prevent hemorrhagic trouble. (225) Only 1 to 2 per cent of good-quality alfalfa meal in the ration furnishes sufficient of this vitamin.

Alfalfa meal also supplies xanthophylls, yellow-colored compounds that give the yellow color, desired on meat markets, to the skin and shanks of poultry. (14)

Commonly, only 2 to 5 per cent of alfalfa is included in formula mashes for chicks and hens, as this proportion of high-quality alfalfa meal is ample. Recent investigations have shown that sometimes both dehydrated alfalfa and sun-cured alfalfa contain a substance which depresses the growth of chicks.[23] However, this depression does not occur unless the percentage of alfalfa meal in the ration is more than 5 per cent.

Even if the alfalfa meal does not contain this growth-depressing factor, the net-energy value of a ration for chickens is decreased when alfalfa meal forms more than about 5 per cent of the entire ration. Turkeys can utilize a larger proportion of alfalfa meal efficiently, good results being obtained with as much as 18 per cent in rations for poults up to

8 weeks of age, and even more for older birds.[24]

Generally, dehydrated alfalfa meal is preferable to sun-dried alfalfa meal for poultry, because it is usually much higher in carotene and other vitamins. However, when poultry rations are mixed on the farm and high-quality alfalfa hay is available, the vitamin A needs of chickens can ordinarily be met by including 5 to 10 per cent of the ground hay in the ration.

ALFALFA IS UNEXCELLED FOR SWINE PASTURE

Alfalfa furnishes pasture over a longer season than most other forages, and it is rich in protein, vitamins, and calcium.

When alfalfa hay of excellent quality is available on the farm, it may be fed to hens in racks, instead of mixing ground hay or alfalfa meal in the mash. There is, however, danger that they will not eat enough of the hay to meet their need for vitamin A.

466. Alfalfa for pasture.—Alfalfa is one of the best pasture crops for swine, horses, and poultry. Cattle and sheep are also often pastured on alfalfa, but it may cause serious trouble from bloat. For pasturing cattle or sheep, it is much safer to use a mixture of alfalfa with a considerable proportion of such grasses as bromegrass, timothy, or orchard grass. Also, trouble from bloat can generally be avoided or reduced by following the practices mentioned previously. (**49**)

Heavy continuous grazing of alfalfa is very apt to injure the stand, and therefore rotation grazing is decidedly preferable. Except possibly where alfalfa thrives best, it is wise to provide a sufficient area of pasture so that considerable alfalfa will grow up to be cut for hay once or twice during the season. A still better plan is to pasture a given field during only part of the season, making one or more cuttings of hay at the usual stage of maturity. Fields should never be pastured until the stand has become well established, and animals should be kept off when the ground is soft, muddy, or frozen. To lessen winter injury in the North, alfalfa should not be grazed closely in the fall. Grazing frosted or frozen alfalfa is believed to cause digestive trouble, which is sometimes serious.

Alfalfa is excelled only by Ladino clover as a pasture crop for swine. Alfalfa furnishes pasture over a longer sea-

son than most other forages, starting early in the spring and remaining green and succulent in midsummer when bluegrass has dried up and even red clover has become hard and woody. The number of pigs should be restricted so as to avoid too close grazing and consequently injury to the stand of alfalfa. Ordinarily, an acre of good alfalfa should carry 8 to 10 pigs weighing 100 lbs. each, with little danger to the stand. Under very favorable conditions, even heavier grazing may be practiced.

The value of alfalfa pasture for pigs is shown by the results of 14 experiments in which alfalfa has been compared with rape pasture, which is the best single temporary pasture crop for swine where it thrives.[25] Spring pigs full-fed corn and a good supplement on the alfalfa pasture gained a trifle more rapidly than others on rape pasture. Also, 10 lbs. less feed was required per 100 lbs. gain on the alfalfa pasture. In addition, over a ton of hay per acre was cut from the alfalfa lots. A further advantage of alfalfa over rape is that rape is not a legume, and therefore does not add nitrogen to the soil. Rape is an annual, and the cost of growing it is therefore somewhat higher than the cost of alfalfa pasture in sections where a seeding of alfalfa will last for 3 years or more.

467. Alfalfa for silage.—Alfalfa and mixtures of alfalfa and grass are used more frequently in this country than any other hay crops for making hay-crop silage, or so-called "grass silage." Even a pure stand of alfalfa generally makes very satisfactory silage when one of the special methods is used which have been described in Chapter XV. It is there pointed out that except in very favorable hay-making weather, making alfalfa into silage conserves the nutritive value of the crop better than in making it into hay by ordinary methods. Making part of the alfalfa crop into silage is of advantage where the weather at haying time is apt to be so rainy that it is difficult to cure hay satisfactorily. Also, if one wishes to produce market milk with the maximum yellow color and vitamin A value in winter, alfalfa silage or other "grass silage" is desirable as part of the roughage, because it is higher than alfalfa hay or corn silage in carotene.

The relative values of alfalfa and other hay-crop silages in comparison with corn silage have been discussed previously. (**436–441**)

468. Alfalfa as a soiling crop.—Alfalfa is one of the best soiling crops, owing to the large yields and to the fact that under proper management it will furnish good feed throughout the entire summer. Much more forage, even twice as much in some cases, is secured from a given acreage as a soiling crop, than when pastured. The use of soiling crops instead of pasture has been discussed in Chapter XIII. (386–387)

469. Alfalfa-grass mixtures.—Except in regions especially well adapted to alfalfa, it is generally best to seed alfalfa in combination with a grass, unless there is a need or demand for pure alfalfa hay. Alfalfa will last longer in such a combination than in a pure stand, because the grass helps prevent winter injury to the alfalfa through heaving. The combination therefore usually yields more forage per acre than alfalfa alone. In addition, an alfalfa-grass mixture resists erosion and the invasion of weeds better than alfalfa alone. Also, such a combination is much safer than alfalfa for pasturing cattle or sheep. There is usually little danger from bloat in pasturing a mixture of alfalfa and grass, if at least one-third to one-half the forage is grass.

Early-cut mixed alfalfa-and-grass hay containing at least one-half alfalfa is fully as palatable to cattle as pure alfalfa. Also, the feeding value is as high for the mixed hay, except that it is, of course, lower in protein than pure alfalfa. Hence, a somewhat greater amount of protein supplement may be needed to balance the ration when such mixed hay is fed.

Of course, first-rate alfalfa hay is much superior to lower grade alfalfa-grass hay. For example, in a recent trial by the United States Department of Agriculture dairy heifers fed U.S. No. 1 alfalfa hay as the only feed gained 90 per cent more than others fed U.S. No.

2 alfalfa-timothy hay that had 34 to 37 per cent fiber.[26]

For swine and poultry, pure alfalfa hay is to be preferred, as it is higher in vitamin content and alfalfa has its greatest value in swine and poultry rations as a source of vitamins. Also, for sheep mixed hay consisting chiefly of alfalfa is better than that made up mostly of grass. For horses and mules, the opposite is true; a mixture high in grass is rated above one high in alfalfa.

Where a field is to be in hay or pasture for 3 years or more, the combination of alfalfa and bromegrass has generally proven superior to alfalfa and timothy or alfalfa and orchard grass in the north central and northeastern states. In a short rotation, timothy is better than bromegrass with alfalfa, because brome is established more slowly. Farther south, alfalfa and orchard grass make an excellent mixture. In the Northwest, alfalfa and crested wheatgrass may be equal or superior to alfalfa and bromegrass.

Bromegrass is so palatable to stock that they are less apt to kill the alfalfa in an alfalfa-brome mixture, than when grazing a pure stand of alfalfa. Another advantage of this mixture is that when some of the alfalfa plants die out, the bromegrass fills in the vacant spaces.

Such a pasture combination as alfalfa-brome is of especial value for dairy cows, since it provides an abundance of highly-palatable and nutritious feed in midsummer when permanent bluegrass pasture is often dried up. In Indiana trials, for example, twice as large an area of bluegrass pasture was needed to provide feed for a given number of cows, as was required of alfalfa-brome pasture.[27] Although 0.3 lb. more concentrates were fed per head daily to the cows on bluegrass pasture, they produced 10 per cent less milk and also did not maintain their weights so well.

III. The Clovers

470. Medium red clover.—Medium red clover (*Trifolium pratense*), commonly called merely red clover, is generally grown in combination with timothy in the United States. For this reason the two are combined in the official crop reports. Clover and timothy is still the most important hay crop in all but a few of the northern states from Iowa eastward. For the entire country the acreage of clover and timothy nearly equals that of alfalfa, but the yield of alfalfa per acre is so much higher that a much greater tonnage of alfalfa hay is produced.

Red clover and timothy are commonly seeded in small grain. The first cutting of hay the year following seeding will have a large proportion of clover, if conditions are favorable, and the second cutting will be mostly clover. The proportion of clover will be much less the next year, except where clover thrives unusually well, and the following year the crop will be nearly all timothy. When grown alone, red clover is usually treated as a biennial.

The value of clover and other legumes in increasing the yields of other crops through the nitrogen they add to the soil is shown in a striking manner by extensive experiments at the Ohio, Pennsylvania, and Missouri Stations.[28] In these studies short-time rotations which included clover have been compared with continuous cropping to corn, oats, wheat, etc. The increases in the value of the grain crops due to the growing of clover were worth even more than the actual value of the clover harvested. Thus, the hay value of the clover crop was less than half its total value.

Red clover does best on well-drained soils rich in lime, but it grows satisfactorily on fields which are a little too acid or not quite well enough drained for alfalfa. It stands severe winters better than alfalfa but does not endure drouth so well, as the roots do not go so deep. On fields that are not uniformly well drained, alsike clover is commonly seeded with red clover and timothy, for alsike will do better on the poorly-drained spots.

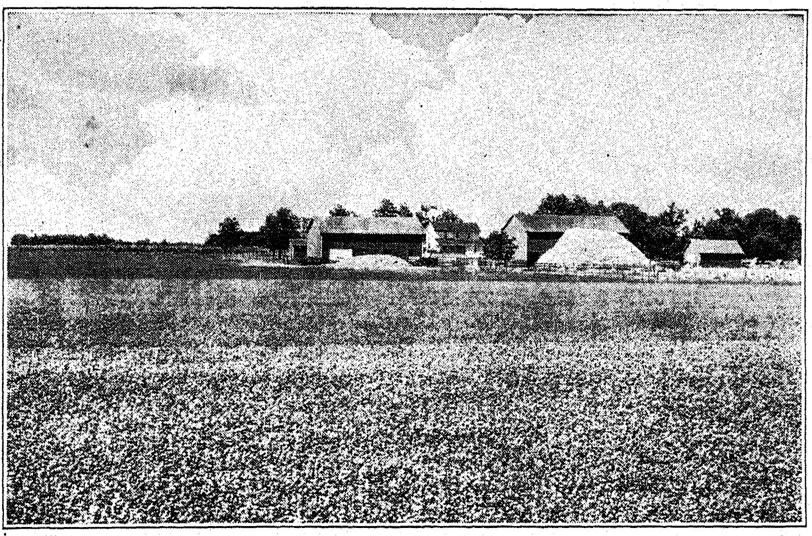
Red clover generally yields a heavy first crop of hay and a much lighter second crop, which is often allowed to mature for seed. When seeded in the spring with a small grain crop, as is the common

practice, clover and timothy will furnish some pasturage the same fall, or even a hay crop if the season is especially favorable. In the southern states, where red clover does not thrive during the heat of summer, it is sometimes grown as a winter annual, the first crop being cut in the spring and the second in early summer.

In seeding red clover, one should be sure to use a strain that is well adapted to the particular locality. Where injury from anthracnose is serious, a resistant variety should be chosen. Red clover from central and southern Europe has been found unsuitable for most clover-growing sections of the United States. Sometimes farmers abandon the growing of red clover because of failure to secure good stands. In most cases such trouble is caused by a lack of lime, phosphate, and possibly potash, or by the use of seed that is not adapted to the locality.

Occasionally, clover is covered with a powdery mildew, and farmers wonder whether there will be any danger in using it for hay or pasture. Apparently, this will not injure stock at all.

471. Red clover hay; mixed clover and timothy hay.—Red clover hay and mixed hay containing a large proportion of clover is second only to alfalfa hay in value for livestock. When cut at the usual stage of maturity, pure red clover hay supplies only about two-thirds as much digestible protein as alfalfa hay. Therefore, in feeding dairy cows and other classes of stock, a somewhat larger amount of protein supplements is often needed with red clover hay than with alfalfa.



A Fine Field of Red Clover for Hay

Red clover, generally grown in combination with timothy, is a very important legume for hay in most of the northcentral and northeastern states.

The difference in protein content and a slightly greater palatability are the chief reasons why alfalfa hay usually sells at a higher price than clover hay of equal quality. Clover hay supplies a trifle more total digestible nutrients than alfalfa and slightly surpasses it in net energy.

Considering both the yield and the quality of the hay, red clover should be cut for hay not later than full bloom.[29] A good plan is to start cutting when about half the plants are in bloom and finish by the full-bloom stage. Such hay will be richer in protein and total digestible nutrients and also more palatable than if cut later. Also, if the first crop is

cut at this stage, the yield of hay or seed in the second crop will be much larger.

The value of mixed clover-and-timothy hay will depend on the proportion of clover present and on the stage of maturity at which it is cut. The more clover there is in the hay, the greater will be its value for all classes of stock except horses. Late-cut mixed hay is a poor roughage for dairy cows or sheep.

Red clover hay, alsike clover hay, or mixed hay consisting chiefly of these legumes is excellent for dairy cattle,[30] beef cattle,[31] and sheep.[32] Except for the fact that a slightly larger amount of protein supplement may be needed to balance the ration when clover hay is fed, it has proven equal or nearly equal to alfalfa hay in feeding experiments with these classes of stock. If the rest of the ration lacks protein, then clover hay will be definitely inferior to alfalfa, which supplies more protein.

Clover hay which is well cured and free from dust or mold is satisfactory for horses and mules, while that of poor quality is not suitable for them.[33] Second-crop clover hay may cause slobbering, for some unknown reason.

Red or alsike clover hay of good quality is a satisfactory substitute for alfalfa hay for pigs or for breeding swine. In Wisconsin and Ohio experiments chopped red clover hay equalled alfalfa hay when used as a vitamin supplement for growing and fattening pigs.[34] If used as the only supplement to grain for swine, clover hay is less efficient than alfalfa hay, for it is less palatable, as well as being lower in protein and calcium.

Clover hay is used for poultry much less commonly than alfalfa, because it usually has less carotene. However, early-cut, well-cured clover hay may be substituted for alfalfa and used in the same manner.

472. Clover for pasture.—Red clover is one of the best pasture crops to be grown in rotations, but it does not usually persist in permanent pastures. For pasturing cattle and sheep, red clover is safer than alfalfa, because there is less danger from bloat. However, with a pure stand of clover, the precautions stated in Chapter II should be taken to avoid this trouble. With mixed clover-and-timothy pasture, which is used for such stock much oftener than pure clover, there is little danger from bloat.

In the northern and central states, red clover is one of the best pasture crops for swine, being excelled only by alfalfa and Ladino clover. In several experiments pigs gained as rapidly on red clover pasture as on alfalfa and required only a trifle more feed per 100 lbs. gain, and in other experiments red clover pasture was slightly superior to rape for swine pasture.[35] There is somewhat more advantage in feeding pigs on clover pasture a protein supplement, in addition to corn or other grain, than there is in the case of alfalfa pasture, for clover is not so rich as alfalfa in protein.

Red clover should not be grazed too closely, or the plants may be killed. Clipping the pasture at the usual time for the first cutting of hay will stimulate new growth.

Red clover or alsike clover is very satisfactory for poultry pasture, being excelled only by alfalfa or by Ladino clover.

473. Clover for silage; as a soiling crop.—Clover or mixed clover and timothy is often used for hay-crop silage and makes good silage when one of the special methods is used which have been described in the previous chapter. The value of such silage in comparison with corn silage for the various classes of stock has been discussed there.

These crops are sometimes used as soiling crops, being cut and fed green to stock. (386) When red clover is cut early, it may furnish 3 or 4 cuttings of green feed a year.

474. Mammoth clover.—This clover (*Trifolium pratense perenne*) is similar to red clover, except that is grows ranker, has coarser stems, and blooms 1 to 2 weeks later. It usually lives 3 years or more and does better than red clover on poor or sandy soil. As it is coarser, the hay is not quite equal to red clover. Since mammoth clover yields only one cutting a season, it is frequently pastured

for several weeks in early spring and then allowed to grow up for hay.

475. Alsike clover.—Alsike clover (*Trifolium hybridum*) flourishes on land too wet or too acid for red clover or alfalfa, if the summers are not too hot. It is somewhat longer lived than red clover, and in an open sward may tend to reseed itself to some extent. Since alsike clover yields but one cutting of hay with some fall pasturage, it is excelled by red clover where the latter thrives. It should be seeded with timothy or other grasses to support the weak stems. Many farmers include some alsike in their seedings of red clover and timothy, especially on the wetter fields. Alsike clover hay is fine-stemmed and fully equal to red clover in value. This clover was once supposed to be a hybrid between red clover and white clover.

476. White clover.—The common types of white clover (*Trifolium repens*) are primarily pasture plants, as they are too low growing to yield hay. White clover thrives best on the heavier soils and where the supply of moisture is ample. It is a moderately short-lived perennial which spreads by means of runners and also reseeds itself under favorable conditions, even when closely grazed. In the North white clover is often important in mixed pastures, forming a dense mat and furnishing feed throughout the growing season. In the South it nearly disappears in summer but reappears in the fall, furnishing winter pasturage and thus combining well with Bermuda grass. When one wishes to maintain white clover in a pasture, it is essential that the pasture be closely grazed. Otherwise, the tall-growing grasses will kill out the low-growing clover.

In the southern states Louisiana white clover and other strains which are taller than ordinary white clover are widely used in permanent pasture mixtures.[36] They generally behave as winter annuals, usually reseeding themselves.

The white clover which often appears spontaneously in many pastures under favorable conditions is usually a wild type with smaller leaves than the common variety (known as "white Dutch clover"). Such wild white clover is longer-lived and apparently better adapted for seeding in permanent pasture mixtures.

477. Ladino clover.—During recent years, Ladino clover, a large-growing variety of white clover introduced from Italy, has become a very important legume in pasture, hay, and silage mixtures in this country.

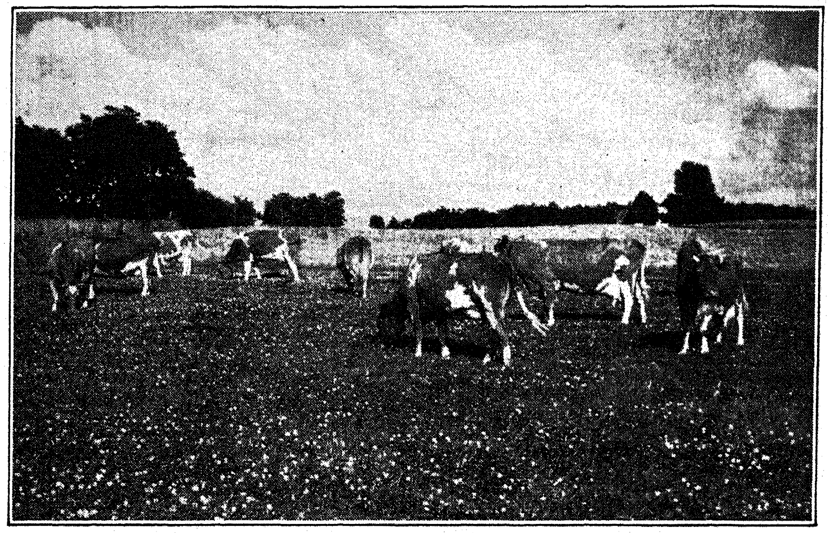
Ladino clover does best on soils well supplied with moisture. Like alsike clover, it will grow on land too wet or somewhat too acid for alfalfa or red clover, but it thrives better when soil acidity is corrected by liming. As it is rather shallow rooted, Ladino clover does not stand drouth so well as does alfalfa. It thrives especially well in the northern states, but is also grown in other sections, including some of the western irrigated districts.

Ladino clover is easily established by seeding in small grain, and the plants spread by means of creeping fleshy stems which root at the joints. It has no upright stalks, as do the other hay-crop clovers or alfalfa. The leaf stems grow up to a height of 10 to 14 inches or even more under favorable conditions. Under proper management Ladino clover will sometimes last several years in a pasture combination, except in some of the extreme northern areas of the United States and in the southernmost states. When the plants die out, Ladino frequently reseeds itself, as some seed is generally produced in a pasture. In the South, Ladino behaves as a winter annual.

Except for poultry pasture and perhaps for swine pasture, it should be seeded with a grass, usually bromegrass, orchard grass, or timothy in the North, and Dallis grass, Bermuda grass, or tall fescue in the South. The clover endures better in a mixture with grass than when seeded alone, as it is less subject to winter injury. Also, a Ladino-grass pasture mixture that has at least about 40 per cent of grass is much less apt to cause bloat in cattle or sheep than pure Ladino pasture. Where alfalfa thrives, it is a good plan to include a little alfalfa in Ladino-grass mixtures.

Ladino pasture is very palatable, and it is unusually rich in protein, low in fiber, and high in total digestible nutrients. On the dry matter basis, Ladino pasture has about 24 per cent protein and only 15 per cent fiber. An especial advantage of Ladino clover for pasture is that it makes more of its growth in summer, and especially in midsummer, than any other perennial grass or legume, except alfalfa.

Unlike ordinary white clover, Ladino pasture ranks ahead of all other pasture crops, because of its great palatability to poultry and its high yield.[37] For swine, Ladino pasture is equal or superior to alfalfa.[38] Ladino clover forage is higher in water than most other legume forage. Perhaps for this reason, dairy cows on Ladino pasture relish some dry hay in addition. Early in the season, Ladino pasture is apt to be very laxative, unless cattle are accustomed to it gradually, or fed hay in addition.



LADINO CLOVER AND GRASS PASTURE

Ladino clover in combination with timothy, orchard grass, or other grasses, provides excellent long-season grazing. (From New York State College of Agriculture, Cornell University.)

dino is killed by continuous close grazing. It should therefore be grazed in rotation, with a rest period of 2 to 3 weeks for new growth between each grazing, or else it should not be grazed too heavily. Ladino should not be grazed more closely than 2 to 3 inches, and in the fall some growth should be left in cold climates for winter protection. If Ladino clover is pastured when the plants and ground are frozen, the stock are apt to injure the fleshy creeping stems severely, through trampling.

Ladino-grass pasture is excellent for all classes of stock and provides forage over a long season. For poultry, pure La-

For hay or silage it is important to cut a Ladino-grass mixture when the Ladino is in early bloom. Otherwise, the grass, which grows much taller when it heads out, is apt to choke out the Ladino. It is difficult to mow a pure stand of Ladino clover unless the mower is in excellent condition, because of the dense growth and the softness of the leaf stems. Also, pure Ladino clover is hard to cure, because the leaves mat together. These difficulties are largely avoided by growing it in combination with grass.

Ladino or Ladino-grass hay is excellent for dairy cows, beef cattle, or sheep. In a New York experiment pure

Ladino hay tended to increase the tendency for oxidized flavor to develop in pasteurized milk on storage, perhaps due to a lower content of vitamin E in the fat.[39] Ladino pasture did not injure the flavor of milk in a Georgia trial.[40]

Early-cut Ladino or Ladino-grass hay or dehydrated meal can be used as a vitamin supplement for poultry or swine in the same manner as alfalfa.[41]

478. Sweet clover.—Sweet clover is an important crop, especially for soil improvement and for pasture, in extensive areas of the United States. It is grown chiefly in the eastern part of the Great Plains, in the corn belt, and in certain districts of the South. The kinds mostly grown are biennial white-flowered sweet clover (*Melilotus alba*) and the biennial yellow-flowered varieties (*Melilotus officinalis*). These varieties are usually seeded in spring grain, and reach maturity and die in August of the following year.

Annual varieties, especially Hubam, are grown in certain areas, mostly for soil improvement. For pasture or hay they yield much less than biennial sweet clover.

Sweet clover stands drouth nearly as well as does alfalfa and will grow on soil too poorly drained or too low in fertility for alfalfa or red clover. However, it requires an ample supply of lime and proper inoculation. In the West it is a good crop for alkali or hard adobe soils. In the North sweet clover is subject to injury from heaving during the winter, the same as alfalfa.

Yellow sweet clover stands drouth and other adverse conditions somewhat better than biennial white sweet clover, and has increased in the Great Plains for this reason. It is finer stemmed, blooms about two weeks earlier, and does not furnish pasture so long the second year.

479. Sweet clover for pasture.—Sweet clover is used chiefly for pasture, especially as a supplement to permanent pasture. Certain later-maturing varieties of biennial white sweet clover are superior to the common kind for pasture, as they provide pasture over a longer period the second year.

At first stock usually dislike sweet clover, on account of the bitter taste, because of the coumarin it contains, but generally they soon become accustomed to it, especially if started on it in the spring, when it is less bitter. Often they will industriously search out every spot of grass and even weeds in the pasture, grazing them to the ground before hunger forces them to the sweet clover. In spite of this lack of palatability, stock usually do well on sweet clover. Sweet clover is less apt than alfalfa to cause bloat in cattle or sheep, but the danger should be guarded against by taking the precautions discussed previously. (49)

The first season's growth of sweet clover may be pastured after it is 8 to 10 inches high and until frost, but close grazing will reduce the yield the following year. The second season the crop will furnish grazing from early spring until the plants die in August, or until they become too woody. By seeding sweet clover in the spring grain each year, it is often possible, if the growth of the first-year crop is good, to pasture the stock on it by the time the second-year crop is exhausted. It will sometimes be necessary to furnish other feed for a brief period. In the southern states second-year and first-year sweet clover, in combination with annual lespedeza, will furnish pasture throughout the entire season.[42]

Some farmers seed sweet clover in the spring without a nurse crop, as a hay or pasture crop for the first season. When thus seeded alone, yields of 1 to 3 tons of hay per acre are secured under good conditions.

In the spring of the second year, grazing should start when the plants are 6 to 8 inches tall, and enough stock should be kept on the field to keep the crop grazed down. If necessary, it should be clipped high, to keep it from blossoming. If it grows up and begins to blossom, it becomes woody and unpalatable and will also set seed and die. As the early growth of sweet clover is very laxative, it is a good plan to supply

stock on such pasture with hay in addition, to prevent scouring.

Sweet clover pasture is particularly useful for dairy cows in July and August when bluegrass pasture is apt to be parched. To furnish pasture at this season, a second-year crop must be closely grazed in the period of rapid growth in the spring. There has been but little trouble from sweet clover producing a noticeable flavor in milk, though sometimes there is a slight change on sweet clover pasture. In South Dakota trials sweet clover pasture was slightly superior to alfalfa and decidedly better than Sudan grass for dairy cows.[43] However, in Wisconsin tests yearling heifers did poorly on sweet clover pasture, apparently because they would not eat enough of it.[44]

Sweet clover pasture has given good results with beef cattle, sheep, and swine. In tests in eastern Washington mixed sweet clover and grass pasture was equal to alfalfa-grass pasture for beef production.[45] Swine take to sweet clover a little less readily than do cattle, but usually become accustomed to it after a time. Experiments show, however, that alfalfa, Ladino clover, red clover, or rape is superior to sweet clover for swine pasture, where these crops thrive.[46]

480. Sweet clover hay; sweet-clover disease.—As a hay crop, sweet clover is inferior to alfalfa or red clover, without considering the danger from sweet-clover poisoning mentioned later.[47] Where sweet clover seeded in spring grain makes sufficient growth after the grain is harvested, it may be cut for hay the same fall, though this will often reduce the yield next year. This crop cures much more readily than the rank growth of the second season and may make hay nearly equal to alfalfa, except for the grain stubble present.

The growth of sweet clover is so rank the second year that it is often difficult to make it into good hay, especially in the humid regions. The fine leaves tend to dry out and shatter before the juicy stems cure sufficiently. In the semi-arid districts the crop is finer stemmed, and the weather is usually better for hay making. Even if the sweet

DAIRY COWS ON SWEET CLOVER PASTURE

If closely grazed during the period of rapid growth in the spring, second-year sweet clover will furnish good pasture in midsummer, as it stands hot weather and drouth well.

clover is cut early and with the mower set to leave a very high stubble, so as to save the buds on the lower parts of the stems, a worth-while second crop is not generally obtained.

Well-cured first-year sweet clover hay usually is about equal to alfalfa hay for dairy cattle, beef cattle, and sheep. It can also be used like alfalfa as a vitamin supplement for swine and poultry. Second-year hay is generally of much lower value. There is apt to be more waste, because of its steminess, and also there is much more danger of it causing sweet-clover disease.

Sweet clover hay and also sweet clover silage which have undergone spoilage may cause *sweet-clover disease.* In this disease the blood loses its power to clot, and the animals may die from internal hemorrhages or may bleed to death from minor wounds. The disease occurs most frequently in young cattle, and rarely affects horses and sheep. The disease is caused by a poisonous compound, dicoumerol, formed when sweet clover spoils, from the coumarin in the plants.[48]

The disease is apparently produced only by moldy or spoiled sweet clover hay or silage, although the spoilage is not always visible. The trouble may be prevented or lessened by feeding sweet clover hay with at least twice as much other roughage, or by alternating it with other roughage in periods of 10 days or 2 weeks, the sweet clover being fed continuously for only this length of time.[49]

481. Sweet clover as a soiling crop or for silage.—Sweet clover is sometimes used as a soiling crop, especially for dairy cows, to supplement short pasture. Sweet clover may be made into silage by using one of the special methods for making hay-crop silage. However, the sweet-clover disease may be caused not only by spoiled sweet clover hay, but also by spoiled silage.

482. Crimson clover.—This annual clover (*Trifolium incarnatum*) is the most important winter annual legume in the southern states. It is grown chiefly in the southeastern states, along the Atlantic seaboard as far north as New Jersey, and in the Pacific Coast region. Crimson clover is widely used in these regions as a winter green manuring and cover crop. It is also important for pasture and hay, and is sometimes used for silage or as a soiling crop. In the extreme North, where the summers are cool and moist, it can be seeded in the spring.

Crimson clover thrives both on sandy soil and also on clay land, if well drained. When it is grown as a winter annual, the crop can be harvested or plowed under as manure early enough so that other crops may be raised the same year.

For temporary winter pasture in the South, crimson clover is commonly seeded with winter grain or with rye grass. If sufficient fall growth is made, the crop will furnish late fall pasture and some winter feed, and then provide excellent spring pasture. Crimson clover is often seeded between the rows of cotton, corn, or sorghum at the last cultivation, as a winter cover crop or for pasture.

Though crimson clover produces plenty of seed in a permanent pasture, the stand of ordinary crimson clover cannot be maintained without reseeding. This is because the seeds germinate readily after the first rain, and the seedlings are usually killed by a dry spell that follows.

To avoid this, reseeding varieties, especially Dixie, have been developed, which have a considerable proportion of hard seeds. For this reason, the seeds germinate over a long period in the fall, and such crimson clover will reseed itself in a permanent pasture, when grown with such grasses as Dallis grass, Bermuda grass, or tall fescue.

For hay, crimson clover should be cut by the time the flowers at the base of the most advanced heads have faded. Cut at this stage, crimson clover hay is about equal to red clover hay. Late-cut hay may injure horses and mules if fed as the chief roughage, for the minute barbed hairs on the blossom heads and stems are then hard and wiry. These hairs may mat together in the digestive

tract, plugging the intestine. To avoid such trouble with late-cut hay, it should be fed with other roughage, or else should be wet thoroughly some hours before feeding it.

Crimson clover silage, made with molasses or phosphoric acid as a preservative, was very satisfactory for dairy or beef cattle in Tennessee tests.[50]

483. Other clovers.—*Alyce clover* (*Alsicarpus vaginalis*) is an annual legume which is used for hay or late summer and fall pasture in some sections of the South. It requires a well-drained, fertile soil. Alyce clover hay equalled annual lespedeza hay in Louisiana trials with dairy cows and in a Mississippi test with beef cattle.[51] In a Florida trial with beef steers it was superior to prairie hay but not so good as alfalfa.[52]

In Florida experiments Alyce clover furnished good pasturage for cows, but for only a short time.[53] Pearl millet was more productive.

Berseem, or Egyptian clover (*Trifolium alexandrinum*), is an annual clover which is adapted to hot climates, growing during the winter season when alfalfa is dormant. It is of much importance in Egypt as a hay crop, as a green soiling crop, and for green manure. Berseem is adapted to such sections of the United States as the Imperial Valley in California. It may be cut several times a season and produces heavy yields under favorable conditions.

The *bur clovers* are low-growing winter annuals that furnish good pasturage in mild regions. They combine well with Bermuda grass, furnishing feed when that grass is dormant in winter, and reseeding unless grazed too closely. In the southern Coastal Plain bur clover offers no advantage for pasture over Dixie crimson clover.[54] Even on land where summer-cultivated crops are grown, bur clover often volunteers in the fall, if once sown. To be sure of its reseeding, alternate strips of the field may be left unplowed to ripen seed.

Two varieties of bur clover are chiefly grown, southern or spotted bur clover (*Medicago arabica*) and California or toothed bur clover (*M. hispida*). Both are more closely related to alfalfa than to the true clovers.

Button clover (*Medicago orbicularis*), is closely related to bur clover. In Tennessee tests it has given promising results as a reseeding winter annual in permanent pastures.[55]

The *hop clovers* (*Trifolium procumbens* and *dubium*) are annual, low-growing clovers that grow wild in various sections and are of importance in permanent pastures in some areas of the South and on the northern Pacific slope.[56] They furnish good early grazing, but disappear in summer.

Persian clover (*Trifolium resupinatum*), a winter annual clover, is a valuable pasture and hay plant of Persia and Egypt and has been found useful in our southern states.[57] Once established with grasses and properly fertilized, it reseeds. It is best adapted to low-lying, heavy, moist soils. It furnishes grazing earlier in the spring than white clover but does not last so long.

Rose clover (*Trifolium hirtum*), an annual clover, which is shorter than crimson clover, reseeds itself and has given good results for reseeding range land in California.[58]

Strawberry clover (*Trifolium fragiferum*) resembles white clover, but has pink flowers. It thrives on soil too alkaline or wet for other legumes and is important in certain western irrigated districts for pasture. In Colorado strawberry clover on a wet seepage field provided excellent pasture for dairy cattle.[59]

Subterranean clover (*Trifolium subterraneum*) is a winter annual which somewhat resembles bur clover. It is an important pasture crop in certain districts of Australia and is adapted to some areas in the southern states and to the coast region of Oregon and Washington. In Australia breeding troubles have been caused in sheep grazing subterranean clover with little grass in the mixture, due to estrogenic hormone in the clover.

IV. Soybeans for Forage

484. Importance of soybeans.—Soybeans (*Glycine max*) have become one of our very important crops, especially in the heart of the corn belt. In recent years 16,000,000 acres or more have been grown annually for all purposes in the United States. This is far greater than the acreage of any of our other annual legume crops. In the leading soybean-growing states—Illinois, Indiana, Minnesota, and Missouri—soybeans are raised on 10 to 21 per cent of the entire crop acreage.

Over 88 per cent of the entire acreage of soybeans is raised for seed, chiefly for the production of soybean oil and soybean oil meal. About 6 per cent of the acreage is grown for hay, and 6

per cent for grazing or as a green manure crop to be plowed under. The uses and value of soybean seed and soybean oil meal for stock feeding are discussed in Chapter XXII.

Soybeans thrive in practically all districts where corn can be grown. They are drouth resistant, are adapted to a wide range of soils, and will do well on soil too sour for alfalfa. Soybeans stand considerable frost, and early varieties can be grown in the northern part of the corn belt. In the southern states on very poor land or on very heavy clays, they are excelled by cowpeas.

485. Soybeans for hay.—Soybeans are often used for hay in the corn belt and other soybean-growing districts. Somewhat over a million acres a year are grown for hay in the United States, with an annual yield of 1.0 to 1.2 tons per acre. Under favorable conditions, soybeans yield up to 2 tons or more per acre of palatable hay which is as rich as alfalfa in protein and is an excellent substitute for alfalfa or clover.

Some farmers include soybeans for hay in their regular crop rotations. Others grow soybeans for hay as a substitute for alfalfa or clover when these crops winterkill. It is generally the best crop for this purpose in sections where soybeans thrive and where the fall weather is suitable for haymaking.

The portion of well-cured soybean hay that is eaten by stock is about equal to alfalfa or clover hay in feeding value. However, there is often a wastage of 10 to 20 per cent in feeding soybean hay, because of the coarseness of the stems. Taking this into consideration, soybean hay of the usual quality is generally worth only 80 to 90 per cent as much as good alfalfa hay.

SOYBEAN HAY IS A GOOD SUBSTITUTE FOR ALFALFA OR CLOVER

Soybeans are especially useful as an emergency hay crop for dairy cows when alfalfa or clover winterkills. They are also grown regularly for hay by many dairymen.

Later-maturing varieties of soybeans are often grown for hay than are used for soybean production. However, in some experiments the common varieties grown for soybeans have equalled the later-maturing hay varieties in yield and quality of hay produced.[60] For hay, soybeans should be seeded rather thickly, so the stems will not be too coarse.

If the weather is suitable, the crop will make good hay at any stage from the time the pods are formed until the beans are almost fully developed and the lower leaves are yellowing, but be-

fore they drop off. In most tests the largest yields of nutrients have been secured when the crop has not been cut before the seeds were well formed. Also, such late-cut soybean hay, if well-cured, has been equal or superior in value for dairy cattle and beef cattle to earlier-cut hay.[61]

This high value for the late-cut hay, which is coarser and less leafy, is due to the fact that a considerable proportion of such hay consists of soybean seed, rich in protein and fat. Appendix Table I shows that the late-cut hay is richer in protein and total digestible nutrients than hay cut when the seeds are first forming. The condition is thus entirely different than in the case of most kinds of hay, such as alfalfa, clover, or timothy, for generally early-cut hay is richer in protein and more nutritious than late-cut hay.

In deciding when to cut the crop for hay, one must, however, consider the weather fully as much as the composition of the plants. In many sections, especially in the northernmost states, soybeans should be cut before the seeds are well developed in the pods, as the weather late in the fall is apt to be poor for haymaking. Also, when the soybean seeds are nearly full size, but still green, they dry out very slowly in the pods, and are apt to mold when the hay is stored.

Soybeans are more readily cured than cowpeas, but it may take twice as long to cure them well as it does to make alfalfa hay. The best hay is made by curing soybeans in cocks, but if labor is limited, good hay can be made under favorable conditions by the use of the side-delivery rake. Even though soybean hay may be discolored by rains, the hay will usually be palatable to stock. If the soybeans do not contain too much grass or weeds, the crop can be cut with a binder and cured in the shock like small grain.

Combinations of soybeans with Sudan grass, sorghum, or millet are often grown, especially for hay. The combination of soybeans and Sudan grass has proved one of the best late-summer emergency hay and forage crops in the central corn belt. The mixture usually yields more forage than soybeans alone, and it is easier to cure into hay. Such hay has a considerably higher feeding value than hay from Sudan grass alone. In the South a mixture of cowpeas and soybeans cures more easily than cowpeas alone.

486. Soybean hay for dairy cattle.—Numerous experiments have shown that soybean hay is excellent for dairy cattle, but that it is not generally equal to alfalfa, because of the greater wastage.[62] If soybean hay is chopped, cows will eat practically all of it, and such preparation increased its value 19 per cent in Wisconsin trials.[63] However, it must be remembered that the stems are high in fiber and low in digestible nutrients. Probably it would generally be more economical to feed a larger amount of the hay and let the cows leave the stems.

Feeding good soybean hay in place of timothy or mixed hay of ordinary quality makes possible a great saving in the amount of protein supplements needed to balance a dairy ration, and also a saving in the total amount of grain or other concentrates required for high production. For example, in trials at the Minnesota Station feeding soybean hay in place of timothy made possible a saving of 46 per cent in the amount of concentrates fed and nearly eliminated any expenditure for purchased protein supplements.[64]

When soybean hay containing a considerable proportion of soybean seed is fed, along with a concentrate mixture containing ground soybeans, the ration may be too laxative or the cows may tire of the excessive amount of soybeans. This may be avoided by feeding some other roughage in place of part of the soybean hay.

487. Soybean hay for other stock.—Soybean hay is a first-rate substitute for alfalfa or clover hay in feeding *beef cattle.* There has been a considerable range in the results of tests which have been conducted to compare these kinds of hay, probably because soybean hay differs rather widely in value.[65] While the very best quality of soybean hay may

equal alfalfa or clover hay in value, probably average soybean hay is not worth more than about 80 to 90 per cent as much as average alfalfa or red clover hay, because of the greater wastage in feeding it.

Sometimes soybean hay which contains a considerable proportion of beans is unduly laxative for fattening cattle, if they are fed too large amounts. Therefore, the allowance had best be restricted to what they will clean up reasonably well.

For *sheep* soybean hay apparently has some decided limitations for use as the only roughage. It has been satisfactory when thus fed to fattening lambs. However, when pregnant or nursing ewes have been fed soybean hay as the only roughage throughout the winter, the results have occasionally been poor in North Carolina studies.[66] In these instances stiffness of the hind legs, inflamed udders, and difficult lambing occurred in the ewes, and stiffness and spasms in the lambs. Similar trouble has been reported elsewhere.[67] It would therefore seem wise to use soybean hay for ewes only in combination with other roughages, such as corn silage.

For *fattening lambs* soybean hay of good quality, fed as the only roughage, has been worth 83 per cent as much as alfalfa or red clover hay in 8 experiments.[68]

Soybean hay is a good feed for *horses* and *mules* when it is well cured. In Mississippi experiments soybean hay was worth 9 per cent more than Johnson grass hay as the roughage for mules at farm work.[69]

For *swine* soybean hay can be used as a vitamin supplement in the same manner as alfalfa hay, if it is leafy and of first-rate quality. Chopped soybean hay was a satisfactory substitute for alfalfa hay in the trio or Wisconsin supplemental mixture for growing and fattening pigs, and soybean hay has also been used satisfactorily for brood sows.[70]

Similarly, for *poultry* chopped or ground soybean hay can be used as a substitute for alfalfa meal. In Ohio tests with laying hens there was practically no difference in the effectiveness of these feeds.[71] Soybean hay for poultry feeding should be early cut and of good quality.

488. Soybeans and soybean combinations for silage.—Good silage can be made from green soybean forage by using one of the special methods that have been explained in the previous chapter. Making soybeans into silage instead of hay is advantageous where the weather at the time in the fall for harvesting the crop is usually too rainy to make good hay.

A mixture of green soybeans with corn or sorghum forage makes first class silage without the addition of any preservative. The corn and the soybeans may be grown separately and mixed at the time of ensiling at the rate of 1 ton of soybeans with 2 to 4 tons of corn forage, or the corn and soybeans may be grown together.

In some of the experiments in which the mixture of corn and soybeans for silage has been compared with corn alone, the combination has produced a larger yield, while in other tests the reverse has been true. The combination silage will be richer in protein, but it is apt to be a little lower in total digestible nutrients and net energy than well-eared corn silage. This is because the amount of soybean seed produced will usually not quite make up for the reduction in amount of corn grain resulting from growing the combination crop. If the conditions are ideal for corn, the soybeans will be shaded so much that they may not form any important part of the crop. Farmers often greatly over-estimate the weight of soybeans in the forage.

In some of the experiments in which corn-and-soybean silage has been compared with corn silage for dairy cows[72] or fattening cattle,[73] the two kinds of silage have been about equal in value and in other tests the combination silage has been worth slightly more per ton. Apparently, in some cases the higher protein content of the corn-and-soybean silage is counterbalanced by the higher grain content of the corn silage.

When one considers the greater amount of protein in the mixed silage

and also the effects of soybeans on soil fertility (if they are properly inoculated), it seems to be a wise practice to grow soybeans with silage corn, if the yield of forage is not reduced.

Soybeans are also sometimes grown with sorghum for silage. In Mississippi tests the value per ton of sorghum-and-soybean silage for beef cattle was not enough higher than that of sorghum silage, to offset the reduction in yield.[74]

Soybeans are not usually grown alone for silage, because the yield is much lower than of corn or sorghum. In Kentucky trials soybean-molasses silage supplied considerably less digestible nutrients than an equal amount of dry matter in corn or alfalfa-molasses silage.[75] The soybean silage was less valuable than corn or alfalfa silage for wintering ewes. In Florida tests soybean silage was less palatable to dairy cows than corn silage, and about 20 per cent was left uneaten.[76]

489. Soybeans as a soiling crop and for pasture.—Soybeans provide a satisfactory soiling crop for fall feeding, though the green forage is usually less palatable to dairy cows than green corn fodder, green alfalfa, or green clover.

Soybeans are a palatable pasture crop for cattle, sheep, and swine. However, they provide forage for only a rather short season, unless care is taken to remove the stock as soon as most of the leaves are eaten off. If this is done, usually new growth will be made, and the crop can be grazed again in about a month. For pasture, soybeans had best be grown in rows to reduce the loss from trampling the plants. Pasturing should not begin until the plants are well grown.

For swine pasture in the northern states rape, alfalfa, or clover is preferable to soybeans, for these crops provide good feed throughout a much longer season and produce more pork per acre.[77] On the other hand, in some sections of the South soybeans produce larger yields of good forage than any other summer pasture crop suited for swine.[78] In using soybeans for fattening pigs, however, care must be taken to avoid the production of soft pork. This difficulty may be largely prevented by using a late variety of soybeans that will not mature seed until after spring pigs are ready for market.

Well-grown pigs make satisfactory gains when they hog down a field of soybeans after the beans have developed, if they receive a limited amount of corn or other grain in addition.[79] Unfortunately, however, this method of feeding produces soft pork, as is pointed out in Chapter XXXIV. The growing of soybeans in a cornfield that is to be hogged down is discussed elsewhere. (704)

V. Other Legumes for Forage

490. Annual lespedeza.—Annual lespedeza has become the most widely grown legume in the South, both for pasture and for hay. Early varieties of lespedeza are grown as far north as central and northern Illinois and Indiana, but lespedeza has its chief importance in the southern states. Lespedeza is used chiefly for pasture, but 4,000,000 to 6,000,000 acres are usually harvested for hay in this country, with an average yield of about 1 ton per acre. On good soils yields of 2 tons or more may be secured.

Annual lespedeza is especially useful because it is very tolerant to soil acidity, it is drouth resistant, and it will grow on soils too poor for alfalfa or clover. However, liming and fertilizing poor acid soils greatly increases the yield. Another great advantage of annual lespedeza is that it reseeds itself in pastures unless pastured too closely. Thus the stand may be maintained year after year without reseeding. It is therefore exceedingly valuable in permanent pastures, as it adds nitrogen to the soil, helps prevent erosion, and furnishes pasturage well liked by stock. Lespedeza is best maintained in a permanent pasture when grown with a non-sod-forming grass, such as timothy, orchard grass, or tall fescue. Lespedeza rarely causes trouble from bloat. Occasionally, horses slobber on lespedeza pasture.

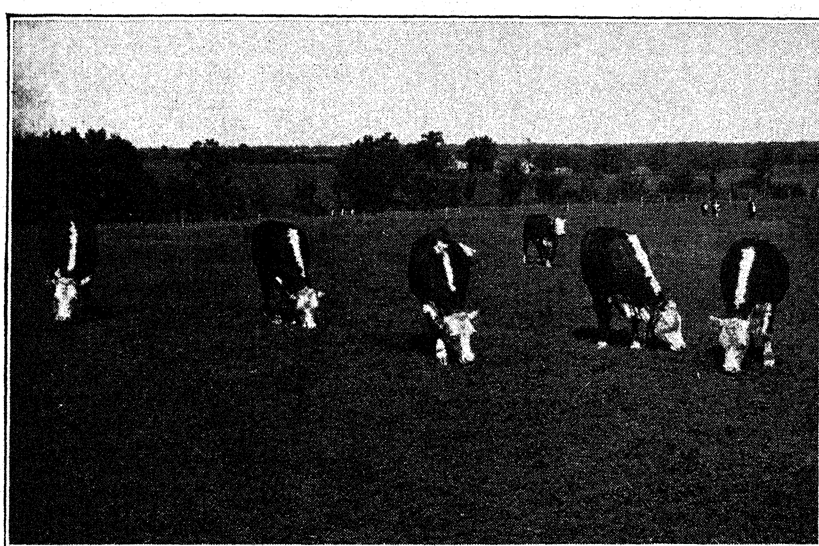
Korean lespedeza (*Lespedeza stipulacea*) is earlier and larger in growth than common lespedeza (*Lespedeza striata*), which is the older type in the

South. Kobe and Tennessee 76 are taller varieties that have been developed from common lespedeza. The forage from all these annual lespedezas has about the same composition and feeding value.

In Missouri a double-cropping system has been developed in which Korean lespedeza follows winter wheat, winter barley, or oats each year.[80] The small grain is grazed or harvested for grain and the lespedeza then comes on and furnishes good pastures or a hay crop.

value. It is of interest that while the stems of most plants contain much more lignin than do the leaves, lespedeza leaves have more of this low-value ingredient and also more tannin than do the stems.[82]

Lespedeza hay cut when in bloom is excellent for all classes of stock, and hay of the best quality may equal or approach good alfalfa hay in feeding value, but is lower in protein, supplying about as much protein as red clover hay.



BEEF CATTLE ON ANNUAL LESPEDEZA PASTURE

The lespedeza volunteered in a crop of oats, and after the oats had been harvested the lespedeza furnished excellent pasture for the rest of the season. (From Etheridge, Missouri Station.)

Lespedeza is fine stemmed and lower in water content than alfalfa, and it therefore is readily cured into hay. It makes much better hay if cut in early to full bloom than when cut later. Experiments have shown that the digestibility of lespedeza hay decreases greatly after bloom, especially when the crop reaches the late seed stage.[81] Late-cut lespedeza hay may be even higher in total protein than early-cut hay, because of the considerable amount of protein-rich seed in the hay. However, it is digested so poorly that it is much lower in digestible nutrients and in feeding

However, the relative value of lespedeza hay, in comparison with alfalfa, has varied considerably in experiments.[83] In some trials it has been fully equal to alfalfa, but in most tests the value has been slightly lower, and in some instances lespedeza hay has been worth only about 80 per cent as much as alfalfa. These differences were probably due to the stage of maturity at which the lespedeza was cut or to the percentage of small grain stubble or other foreign material.

Good-quality lespedeza hay is very satisfactory for dairy cattle, beef cattle,

sheep, horses, and mules. It can also be used in place of alfalfa hay as a vitamin supplement in feeding swine and poultry. In South Carolina tests ground lespedeza hay was even higher than alfalfa leaf meal in carotene, and in Tennessee trials, 5 per cent of lespedeza leaf meal was as satisfactory as alfalfa meal in rations for chicks.[84]

Moldy lespedeza hay may cause a hemorrhagic disease in cattle, similar to the sweet-clover disease.[85] (**480**)

Lespedeza pasture is excellent for dairy cattle, beef cattle, horses, and mules. It does not start growth early in the spring and is killed by hard frosts, and it thus does not furnish pasture over as long a season as does alfalfa or Ladino clover. It is therefore best used in combination with grass or winter grains, which furnish pasture earlier in the spring and also later in the fall.

491. Sericea lespedeza.—In addition to the annual lespedezas, a perennial lespedeza, called sericea lespedeza (*Lespedeza cuneata*) is grown in the southern states for hay, for pasture, and for soil improvement. This perennial lespedeza grows much taller and coarser than the annual varieties, and outyields all other hay crops on poor land.

Unfortunately, ordinary sericea lespedeza is so high in tannin, especially in later stages of growth, that it is unpalatable to stock. If it is cut for hay when not over 10 to 15 inches high, stock will usually eat the hay reasonably well, though there will be some wastage. When cut at this stage of growth, 2 or 3 cuttings of hay can be obtained a year. In cutting the crop, the stubble should be left 2 to 3 inches high, as the new growth comes from the lower part of the stems, and not from the crowns, as with alfalfa or red clover.

Fortunately, a low-tannin variety of sericea lespedeza has recently been developed, which is much more palatable to stock.[86]

The value of ordinary sericea lespedeza hay has varied widely in feeding experiments.[87] In most tests it has been decidedly inferior to annual lespedeza hay or alfalfa hay for dairy cows, beef cattle, or sheep. In a recent Alabama experiment 6-month old dairy calves would eat only half as much sericea hay (cut when 15 inches high and well cured) as they did of early-cut alfalfa hay.[88] They lost weight on the sericea hay and gained well on the alfalfa. Not only was the sericea hay unpalatable, but also only 45 per cent of the dry matter was digested.

When sericea lespedeza is pastured, grazing should begin in the spring when the plants are only 8 to 10 inches high or even less, and enough stock should be pastured in the field to keep the plants from growing up tall and unpalatable.[89] Even then, cattle have sometimes done very poorly on the pasture.

Sericea lespedeza silage has also been less palatable than alfalfa silage or corn silage, and usually worth less per ton.[90]

492. Cowpeas for forage.—The cowpea (*Vigna sinensis*) is a hot-weather annual legume which may be grown from the central part of the corn belt southward. This viny legume, which thrives fairly well on all types of soil, is one of the most important legumes in the cotton belt. Here cowpeas do better than soybeans on the poorer soils, but on the better soils, or even on poor soils when well fertilized, soybeans are usually more productive.

Cowpeas are grown chiefly for forage and for green manure. They also furnish seed for humans and animals, though the seed is usually too high priced for stock feeding. The use of the seed for feeding is discussed later. (**848**)

The common varieties of cowpeas do not mature in a definite time, but continue to put forth new growth and bear pods over a long period. The crop is usually cut for hay when the first pods ripen, but harvesting may be delayed considerably without loss, unless the leaves start to shed. Though the average yield of cowpea hay in this country is only 0.8 ton per acre, the crop will give a yield of 1 ton or more on fertile soil. In the South cowpea hay is frequently called "peavine hay."

Because cowpea hay is rather difficult to cure, it is generally cured in high and narrow cocks, after it has dried out sufficiently in the windrow. Sometimes the hay is cocked about frames or pyramids of poles to permit better air circulation. For hay, cowpeas are often grown with Sudan grass or sorghum to support the vines and to permit easier curing.

Cowpea hay is richer than alfalfa hay in protein and as high in total di-

gestible nutrients. When of good quality, it is equal or nearly equal to alfalfa or clover hay for dairy cattle,[91] beef cattle,[92] sheep,[93] or horses and mules.[94] Well-cured chopped or ground cowpea hay can also be used as a vitamin supplement in feeding swine.[95]

The value of cowpea hay as a source of protein to balance rations is well shown by 3 New Mexico experiments.[96] Steers fattened on a ration of cowpea hay, ground milo grain, and sweet sorghum silage gained as rapidly as others fed cottonseed meal in place of the cowpea hay and sold for just as high an average price. On the average the home-grown cowpea hay was worth 59 per cent as much per ton as cottonseed meal in balancing the ration.

Cowpeas are extensively grown with corn or sorghum, and the crop grazed by cattle, sheep, or pigs. Sometimes more or less of the corn ears or cowpea seed is picked by hand before the stock is turned in. Cowpeas, grown with corn or sorghum, make good silage.

493. Bean forage.—*Field* or *navy beans* (*Phaseolus vulgaris*) are grown for human food instead of for feeding livestock, but the cull beans, discolored or otherwise unsuited for human consumption, are fed to livestock, and also the bean straw, commonly called "bean pods." The use of cull beans and bean straw is discussed on other pages. (844, 513)

Mung beans (*Phaseolus aureus*) have proven to be a good annual hay crop for certain sections of the southern plains. Mung beans resemble cowpeas in growth, but are coarser and less viny. They produce fair yields on poor soils where alfalfa will not thrive and are generally not injured by disease or insects. The green variety is finer stemmed than golden mung beans and yields considerably less forage, but more seed. The use of the seed for feeding is discussed later. (844)

Mung beans should be cut for hay when the pods are well developed, but when only a few have turned brown. Curing had best be finished in cocks, as the forage cures slowly. In Oklahoma tests mung-bean hay was very satisfactory for dairy cows, but on account of the stemmy nature there was more wastage than of alfalfa hay.[97] Golden mung-bean hay, as fed, was worth nearly as much as alfalfa hay per ton, while green mung-bean hay was of slightly lower value. In an Arkansas trial chopped mung-bean hay equalled alfalfa hay for dairy heifers.[98]

In the Oklahoma tests mung beans made satisfactory silage without any preservative, and the silage did not have a strong odor. It required 285 lbs. of mung-bean silage to equal 100 lbs. of alfalfa hay in value.

In certain sections of the Southwest, *tepary beans* (*Phaseolus acutifolius*) are a better hay crop than soybeans or cowpeas, as they are more resistant to drouth and heat. Tepary-bean hay equalled alfalfa or cowpea hay for dairy cows and heifers in Oklahoma tests.[99]

Sometimes silage is made from *green lima bean* vines or *snap bean vines*, after the green beans are removed. The palatability and value of such silage apparently differs widely, depending on how green the leaves were and on how the silage is made. Lima bean silage of good quality was satisfactory for dairy cows in Delaware experiments, though less palatable and somewhat less valuable than corn silage.[100]

Dehydrated bean vine meal, made from green snap bean vines after the beans were picked, compared favorably with alfalfa meal as a vitamin supplement for chicks in a Florida test.[101] Meal made from vines after the leaves had matured was decidedly inferior.

494. Birdsfoot trefoil; big trefoil.—*Birdsfoot trefoil* has recently become important in some of the northern states as a promising perennial pasture and hay legume. When once well established, it will endure many years in pasture or hay mixtures, for it is very winter hardy. It will grow on land too poor or too sour for alfalfa. Also, it is suited to a wide range of soils, it is more drouth tolerant than white or red clover, and it will stand a moderate amount of alkali. Birdsfoot trefoil has not been known to cause bloat. In composition and feeding value, the hay compares favorably with alfalfa, and the pasture with white clover.[102] Two cuttings of hay can be made a year. Where alfalfa, red clover, or Ladino clover thrive, they outyield birdsfoot trefoil.

Broad-leaved birdsfoot trefoil (*Lotus corniculatus*), the kind most commonly grown, is best adapted to dryer and less fertile soils. It is deep rooted and stands drouth very well. The narrow-leaved birdsfoot trefoil (*Lotus tenuis*) is adapted to moist and fertile soils and is less drouth resistant. In most areas it is inferior to the broad-leaved kinds.

Unfortunately, birdsfoot trefoil becomes established slowly, and the yield is low the year after seeding. Also, it is sometimes diffi-

cult to secure a satisfactory stand. There are two types of broad-leaved birdsfoot trefoil, the Empire variety selected by the New York (Cornell) Station from plants that had persisted for many years on hill land in eastern New York, and the European strains. The latter are more erect in growth, have greater seedling vigor, and recover more quickly after cutting. However, they apparently do not persist so long in pastures. Viking, Granger, and Cascade are varieties of this type.

In many of the northern states from New England to the Midwest, birdsfoot trefoil has given excellent results, being considered the most promising legume for permanent pastures or hay fields.[103] In other states the results have not been favorable.[104] Since birdsfoot trefoil is slow to become established, it should not be used in short crop rotations.

For hay, birdsfoot trefoil should be seeded with a strong-stemmed grass, such as timothy, orchard grass, or brome grass, to support the weak stems and prevent lodging. For pasture, it should be seeded with one of these grasses or with Kentucky bluegrass.

Big trefoil, or marsh trefoil (*Lotus uliginosus*), which is grown but little in this country and which is not winter hardy, grows on wet land, even on marsh land.[105]

495. Crotalaria.—Crotalaria, an annual legume, is grown in the southern states, especially in Florida, for green manure. The kind grown most commonly for this purpose is *Crotalaria spectabilis.* This and some other species are poisonous to livestock, the seed being especially toxic.[106] Many animals have been killed by grazing these crotalarias.

Crotalaria intermedia and certain other species, on the other hand, are entirely harmless. *Crotalaria intermedia* produces a high yield of forage, but the pasture is not very palatable and cattle have to learn to eat it.[107] The plants produce a considerable proportion of hard seed, and it volunteers in pastures. The crop makes satisfactory silage, but the hay is apt to be stemmy and unpalatable.

496. Desmodium; Kaimi clover.—*Beggarweed,* or tall tick clover (*Desmodium tortuosum*), is an annual legume which has rather woody stalks 3 to 10 feet high bearing abundant leafage. This and other desmodiums are used for green forage and hay production in subtropical regions.[108] Beggarweed does well on sandy land. It should be cut for hay at the beginning of bloom, before it becomes too coarse and woody or the lower leaves drop off. Such hay is relished by stock, but the greatest value of the crop is for grazing.

In tests in Guatemala meal made from another desmodium (*Desmodium intortum*) was a satisfactory substitute for alfalfa meal in chick rations.[109]

In Hawaii *Kaimi clover* (*Desmodium canum*) is becoming the most important grazing legume in humid lowland pastures.[110]

497. Flat pea.—The flat pea (*Lathyrus sylvestris*) is a perennial legume that shows promise of meeting the need for a pasture plant which will produce a satisfactory yield on logged-off land in the northern Pacific Coast states, and which will compete with bracken fern and underbrush and not dry up in midsummer on hilly land.[111] The forage is exceedingly rich in protein, having 20 per cent or more of digestible protein on the dry basis, and also is high in total digestible nutrients. Unfortunately, the seed is poisonous to stock when they consume too large amounts. There may therefore be some danger in pasturing flat peas when much seed has formed.

498. Guar.—Guar (*Cyamopsis tetragonoloba*) is a coarse, upright annual legume grown in India for seed for human consumption and for forage. In Texas tests stock, except sheep, refused to graze guar, because of the very hairy, nettling leaves.[112] If the forage was cut and wilted, it was eaten readily.

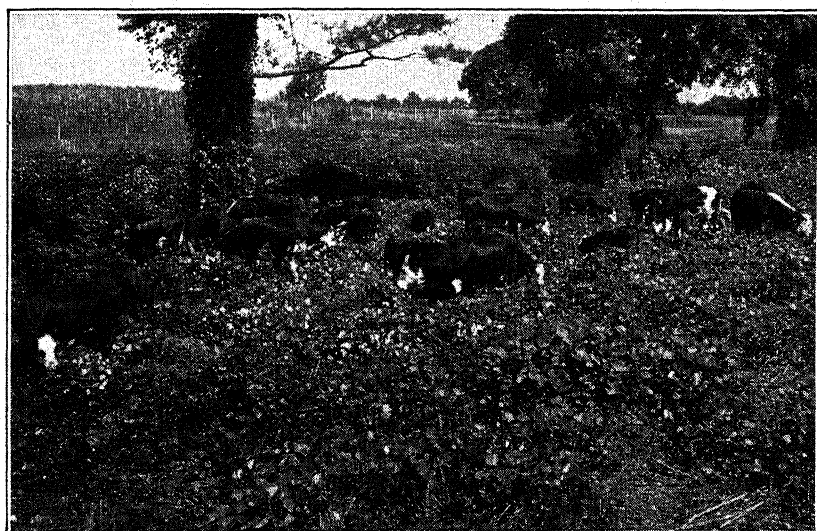
499. Indigo.—Hairy indigo (*Indigofera hirsuta*) is a coarse-growing annual summer legume sometimes used for pasture or hay in Florida and the southern Coastal Plain. It reseeds itself in pastures unless grazed too closely. Hairy indigo grows fairly well on rather poor sandy land and has a low lime requirement. Sensitive to cold, it is killed by the first frost.

Good results have been secured at the Florida Range Cattle Station when hairy indigo-grass pasture has been used in combination with other pasture.[113] When grazed continuously on hairy indigo alone, it produced lameness in some animals, apparently due to some toxic effect. It should therefore be seeded in combination with grass.

Creeping indigo (*Indigofera endecaphylla*) is a promising annual legume to be used in combination with grasses in high rainfall areas of the Hawaiian Islands.[114] Unfortunately, if it forms over half of the forage it has a toxic effect on cattle and sheep. Creeping indigo meal produced satisfactory results when it formed not more than 2.5 per cent of a ration for growing chickens, but 5 per cent depressed growth.

500. Koa haole.—Koa haole (*Leucaena glauca*), a shrubby perennial legume, is grown extensively on drier range land in Hawaii.[115] If it forms too large a part of the feed for horses, swine, chickens, or rabbits, it may cause illness. However, dairy cows have been fed koa haole soilage as the only roughage for more than 3 years without injury. Feeding the kao haole, which is rich in protein, made unnecessary the purchase of expensive protein supplements. However, it yielded only about one-third as much forage per acre as Napier grass.

Kudzu usually forms but little seed and the seed does not germinate well under field conditions. The crop is therefore propagated by setting out crowns, vine cuttings, or seedlings. It requires from 1 to 5 years to become fully established, but it then persists long under proper management. It will not stand close, continuous grazing, but may be pastured moderately until early fall. The stock should then be taken off, so that a new crop of leaves can be put forth and the food reserves built up in the roots, before freezing weather kills the leaves. Otherwise, it is apt



Beef Cattle on Kudzu Pasture

In the southern states kudzu prevents erosion on hilly land and furnishes a high yield of good pasturage or hay. It supplies an abundance of feed in midsummer, when permanent pastures are commonly poor. (From Mississippi Station.)

to winterkill. After the leaves have died, kudzu will furnish a month's grazing without injury to the stand.

Koa haole meal or fresh leaves satisfactorily replaced alfalfa meal in rations for laying hens and for chicks.

501. Kudzu.—Kudzu (*Pueraria thunbergiana*) is a rapid-growing perennial legume vine that has become very important during recent years in the southern states. Here it prevents soil erosion on hilly land and furnishes a high yield of good pasturage or hay. The viny branches grow many feet along the ground, rooting at the joints and forming new crowns, from which twining shoots 2 to 4 feet high are sent up. These may be cut with a mower without great difficulty, particularly with a special device on the cutter bar to separate the cut and uncut forage.

Kudzu furnishes excellent legume pasture from late spring all through the summer, supplying an abundance of feed in midsummer, when permanent pastures are usually poor. In experiments it has been satisfactory for dairy cattle,[116] beef cattle,[117] swine,[118] and poultry.[119] Pigs will somewhat more than maintain their weights on kudzu pasture alone, without grain, and may thus be carried along to be fattened in the fall on a crop of corn or peanuts. When fed grain, without any protein supplement, on kudzu pasture pigs make good gains. Kudzu is also a good grazing crop for poultry.

Kudzu should not be cut for hay until it is well established, and then not more than 2 cuttings a year should be made, or else the stand will be injured. Kudzu cures into hay rather easily, and the hay is about as rich as alfalfa in protein. Good-quality kudzu hay has given good results with dairy cattle, beef cows, or fattening cattle.[120] It is too coarse and stemmy for calves. Kudzu can also be made into silage.[121] Dehydrated kudzu meal or leaf meal is a good substitute for alfalfa meal for poultry or swine.[122]

Ordinary kudzu does not do well in the tropics, but *tropical kudzu* (*Pueraria phaseoloides*), a close relative, fills a need for a vigorous, perennial legume which covers the ground quickly from seed.[123] It is relatively resistant to drouth, grows well in moderate shade, has no serious diseases or pests, and makes good pasture. It is a common crop in Java, Sumatra, and Malay and is proving well adapted to Puerto Rico.

502. Lupines. Lupines (*Lupinus* spp.) are grown in the Gulf Coast states as an annual winter crop, and in some localities produce more green material than any other winter legume.[124] The varieties generally grown in the South as a cover crop are poisonous to stock, but sweet lupine varieties have been developed which make good pasture. However, some of the seed sold as sweet lupine contains considerable of the bitter, toxic kind.

503. Peas for forage; peas and oats.—Field peas (*Pisum arvense*), the use of which as a grain crop is discussed in Chapter XXII, are grown in Canada and the northern states to some extent for forage. They do not thrive where the season is hot. A combination of peas and oats, if cut early and well cured, makes hay which is slightly richer than red clover hay in protein, but usually not so palatable. In trials with fattening lambs oat-and-pea hay has been decidedly inferior to alfalfa hay, being worth only about three-fourths as much per ton.[125]

Peas and oats make satisfactory silage, if not ensiled until the oats are in the dough stage and the peas have hardened. Such silage is not quite equal to corn silage but is useful north of the corn belt, especially as an emergency silage crop when alfalfa or clovers winterkill.[126]

Peas and oats are sometimes sown as a spring soiling crop, especially for dairy cows, and are one of the best early annual crops for this purpose.

Peas and oats are sometimes used as pasture, especially for swine. However, the crop does not furnish pasturage over a very long season, and stock may tramp down and waste considerable of the forage. For pasture this mixture is therefore excelled by rape or by a combination of oats, peas, and rape.[127] By sowing rape with peas and oats, pasture may be provided until late fall if conditions are favorable, for the rape will come on after the peas and oats are grazed off.

Austrian winter peas are sometimes grown in combination with winter oats or other winter grain for winter and early spring pasture in the southern states and in certain sections of the Pacific Coast district. Occasionally, a peculiar lameness occurs in pigs on Austrian winter peas, apparently due to some injurious substance in the peas.[128]

504. Lambing or hogging down field peas.—In certain localities of the West, field peas, usually sown with a small amount of oats or barley to support the vines, are sometimes grown for lambing down by fattening lambs or for hogging down when the crop is nearly mature. Unfortunately, serious death losses from "overeating disease" frequently occur among lambs grazed on field peas. The method is therefore used much less than formerly.[129]

Fairly good gains are made by pigs hogging down peas, if the vines are still green. In North Dakota tests 385 lbs. of pork were produced per acre of peas hogged down, and in Idaho tests 406 lbs.[130] More rapid gains are made when the pigs are fed a limited amount of grain in addition to the peas, and the results may be still better when a small amount of high-quality protein supplement, such as tankage or meat scrap, is also fed.

505. Pea-cannery waste; pea-vine silage.—*Pea-cannery waste* consists of the pea vines and empty pods, left after the green peas are removed at the pea-canning factories. It is usually put in large stacks, where the decaying outside layer preserves the mass of silage within, or else it is put in silos. No preservative is needed, because the peavines are rich in sugar.

The *pea-vine silage* has a strong odor, but is an excellent feed for dairy cows, cattle, and sheep. It contains considerably more digestible protein than corn silage, but it supplies less total digestible nutrients. The silage is rich in carotene. Where advantage can be taken of its richness in protein by saving on protein supplements that would otherwise be needed to balance the ration, pea-vine silage is worth 90 per cent as much as well-eared corn silage per ton. If fed in a ration

that contains more protein than needed, pea-vine silage is probably worth only about 75 to 85 per cent as much as well-eared corn silage.[131]

Though pea-vine silage has a strong odor, it does not injure the flavor of milk, if fed after milking in a well-ventilated barn and if spoiled portions are discarded. For fattening cattle or lambs, pea-vine silage gives the best results when fed with some hay.

Dehydrated pea vines were a good substitute for alfalfa meal as a vitamin supplement for chicks in a Maryland test and for pigs in a Washington trial.[132]

506. Peanuts for forage.—Peanuts (*Arachis hypogea*) are grown chiefly for the underground nuts. However, when peanuts are raised for market, the forage is a valuable by-product. The peanuts are usually harvested with a digger which cuts off the lower roots and lifts the plants with the nuts attached.

A common method of curing the crop is to stack the plants, after the leaves have wilted somewhat, about stakes set in the ground, with cross pieces on them to keep the plants off the ground. After curing for 3 to 6 weeks, the nuts are picked from the vines by a threshing machine, leaving as a by-product the cured forage, usually called "peanut hay" instead of "peanut straw."

Such peanut hay, if well cured, leafy, and not moldy, is of much higher value than one might estimate from its appearance, and it is so palatable to stock that it is eaten with surprisingly little waste. Good-quality threshed peanut hay is lower in protein than alfalfa or soybean hay. However, it is higher than these hays in nitrogen-free extract and lower in fiber, even though it has all of the stems and also some roots. Peanut hay practically always contains some dirt or other foreign material. Therefore, it is a good plan to shake the dirt from the hay or to feed it in a rack, so the stock can refuse the coarsest stems, if they wish, and so any dirt will fall out.

The average yield of threshed peanut hay is about one-half ton per acre, and usually more than a ton of hay is secured for each ton of unhulled peanuts.

Sometimes the peanut plants are cured in windrows, a side delivery rake being used to turn the vines at intervals of several days. Unless the weather is very favorable, most of the threshed hay obtained by this method is badly discolored, very stemmy, dirty, and rather unpalatable. Low-grade peanut hay may not be much higher than small-grain straw in feeding value. Moldy peanut hay or that which carries much dirt or dust is not suitable for horses or mules, as it may cause digestive trouble.

In experiments in which threshed peanut hay has been fed to dairy cattle,[133] to beef cattle[134] and to sheep[135] the results have differed greatly, undoubtedly depending on the quality of the peanut hay. In some of the trials peanut hay has been nearly equal to good alfalfa, lespedeza, or cowpea hay. However, in other tests the peanut hay has been much lower in value.

The residue from dusting the growing peanut vines with sulfur or copper-sulfur fungicide to control disease has not injured stock fed such hay.[136]

The hogging down of peanuts is discussed later. (839) When peanuts are grown for this purpose, the peanut vines are sometimes mowed and cured into hay before the hogs are turned in. Such hay is fully equal to alfalfa or lespedeza hay in value.

The entire cured peanut plants, including nuts, also make a first-rate feed. In North Carolina tests, when ground peanut plants, including nuts, formed half the concentrate mixture for dairy cows, the milk production was as good as with a concentrate mixture made up of ground corn, ground oats, cottonseed meal, and wheat bran.[137] Good results were likewise secured when peanuts and vines were fed to dairy cows or fattening cattle in other tests.[138]

507. Pigeon pea.—The pigeon pea (*Cajanus cajan*) is a legume shrub which is grown in the tropics for its edible seed. In Hawaii it was raised extensively as a grazing crop for beef cattle, and as a protein-rich soiling crop for dairy cows. However, the acreage has declined greatly, because it yields much less forage per acre than Napier grass, and because it is short lived.[139]

508. Serradella.—Serradella (*Ornithopus sativus*) is cultivated to some extent in Europe on poor sandy land, as it will grow on soil too acid for most legumes. Though it has often been tested in the United States, it has proven inferior to other crops, even on acid, sandy soils.

509. Singletary peas.—Singletary peas (*Lathyrus hirsutus*), also called Caley peas, rough peas, or wild winter peas, are used in the Gulf Coast states to some extent for supplementary grazing in late winter and early spring.[140] The singletary pea is a viny annual winter legume, resembling vetch. The seed is poisonous to stock, and the crop should not be pastured after pods have formed. An

advantage of singletary peas is that they produce much more seed per acre than such legumes as vetch, and the seed is therefore cheaper.

510. Velvet beans.—Velvet beans (*Stizolobium*, spp.) are vine-like annual legumes grown throughout the cotton belt, except in the extreme northern part. They grow well on poor, sandy soil and on soil deficient in lime, provided it is well drained. Even the early varieties make a tangled mass of vines 3 to 10 feet long, while the later ones may run to 30 feet or more.

Velvet beans are difficult to cure into hay, and over 90 per cent of the acreage is grown in combination with corn to support the vines. The crop is commonly used for grazing, after most of the ears of corn and perhaps some of the ripe beans have been picked by hand. On sandy soil the leaves, vines, and pods do not decay readily after they are killed by frost, and the crop often furnishes feed until early spring.

Velvet beans furnish good pasture for cattle and sheep, but not for swine.[141] With fattening pigs the gains are usually satisfactory as long as the corn lasts, but then they are often poor.[142] This is because velvet bean seed is unsatisfactory for swine when forming any considerable part of the ration. (856)

Silage may be made from the combination of velvet beans and corn. Though it has a very dark color, it is eaten readily by stock.

The use and value of velvet-bean seed, of velvet beans in the pod, and of velvet-bean feed are discussed in Chapter XXII.

511. Yellow trefoil, or black medic.—Yellow trefoil, or black medic (*Medicago lupulina*), a relative of alfalfa, is a creeping legume, usually an annual, which is somewhat like white clover in habit of growth. It is commonly not prominent in permanent pastures, except on the black prairie soils of Alabama and Mississippi, where it occasionally furnishes a considerable part of the pasturage in early spring. Because of its small size, yellow trefoil is less productive than other legumes that may be grown.

512. Vetch.—The vetches raised in the United States are grown chiefly as winter annuals for hay, for pasture, or for soil improvement in the extreme southern states and in the northern Pacific Coast region, where the winters are not severe. Vetch is also grown in some of the northern states, especially on sandy soils, being seeded either early in the spring or in the fall. Vetch is a cool-weather crop and does not thrive in summer in the central states.

For hay, vetch is usually sown with small grain to support the weak vines, which may clamber 4 or 5 feet or more in a tangled mass. The hay is easy to cure but somewhat difficult to handle because of its tangled nature. Pure vetch hay is about equal to clover hay in value, and yields of 2 tons or more per acre are secured under favorable conditions. The value of oats-and-vetch hay will depend somewhat on the proportion of vetch. In Oregon tests oats-and-vetch hay was not satisfactory as the only roughage for fattening lambs.[143]

The vetches also furnish excellent pasture for stock, the crop sometimes being pastured when young and then being allowed to grow up for hay or seed. In a Mississippi test dairy cows grazed on vetch-and-oats pasture in winter produced decidedly more milk than others kept on permanent pasture.[144]

The combination of vetch and oats also makes good silage. In the coast sections of Oregon and Washington this combination is often sown in the fall and ensiled in early summer. In Oregon trials the average yield of vetch and oats for silage was 16 tons per acre, which was double that of corn.[145] The vetch-and-oats silage was as palatable as corn silage and equalled it in feeding value. In Canadian trials oats-vetch-and-pea silage was slightly inferior to corn silage for milk production.[146]

The two kinds of vetch most commonly grown in the United States are hairy or winter vetch (*Vicia villosa*), also called sand vetch, and common vetch (*Vicia sativa*). Both are ordinarily annuals, although hairy vetch may behave as a biennial when seeded in the spring. Hairy vetch is more winter hardy and more drouth resistant than common vetch, and may be grown on poorer soils. Other kinds of vetch grown to a lesser extent are Hungarian vetch, Monantha vetch, and purple vetch. Vetches are sometimes called tares.

513. Legume straw or chaff.—The straw or chaff that is left after ripe leg-

umes are threshed for seed is often used for stock feeding. Legume straw contains much less protein than hay made from the same crops and is much higher in fiber and therefore lower in total digestible nutrients. If the legume straw contains a considerable proportion of leaves, the protein content will be decidedly higher than that of straw from the small grains.

The value of legume straw or chaff varies widely, depending chiefly on the proportion of leaves and the manner in which it was cured. It can be fed satisfactorily as part of the roughage to dairy cattle, beef cattle, or sheep, but it is often too dusty for feeding to horses. Legume straw gives much better results when it is fed as only part of the roughage, along with good legume hay or else with silage, than when it is the only roughage.

Alfalfa or clover straw, when well cured, is of greater value than straw from the coarser legumes, such as soybeans or field beans. In an Idaho trial alfalfa or clover straw was worth about one-half as much as alfalfa hay when it replaced part of the hay in a ration for fattening lambs.[147] On the other hand, when alfalfa or clover straw has been fed as the only roughage or the chief roughage to fattening lambs or the breeding flock, the results have usually been unsatisfactory.[148]

Bean straw from field or kidney beans, often called "bean pods," is used for feeding cattle, sheep, and horses in the bean-growing districts. Its value varies widely, but when of good quality it is satisfactory as part of the roughage when fed with good hay. Thus fed, it is worth about as much as corn or sorghum fodder, or one-half as much per ton as alfalfa or clover hay.[149]

Lespedeza straw of excellent quality, cured without exposure to rain and containing a high proportion of leaves, was a satisfactory substitute for good soybean hay in an Illinois trial with dairy cows, when both were fed with corn silage and a suitable concentrate mixture.[150] Though the lespedeza straw did not seem so palatable as the soybean hay, the cows actually wasted a smaller percentage of it.

Pea straw from field peas varies widely in value, and straw from combine threshing is worth less than that from a stationary thresher, as the pea vines are usually more mature when the crop is harvested and the straw has less leaves. Pea straw had best be fed as not over half the roughage, along with good legume hay or silage.[151] Thus fed, its value will range from less than half to three-fourths that of alfalfa hay.

Soybean straw usually consists chiefly of the coarse stems with a very small proportion of leaves, and it therefore has a low feeding value. It should be fed as only part of the roughage, preferably along with some good legume hay. Also, it had best be used for animals that are not being fed for high production. For example, it is more satisfactory for dry cows or for heifers than for cows in milk.[152] When fed as the only roughage for fattening lambs in an Illinois trial, soybean straw gave poor results, even though sufficient protein supplement was fed to balance the ration.[153] The straw, which had only 3.4 per cent protein, was worth but one-fourth as much as alfalfa hay. The soybean crop had a much higher value as hay than when fed as soybean straw plus soybean seed.

QUESTIONS

1. State 9 advantages of legume forages.
2. Why should livestock farmers grow a large acreage of alfalfa wherever the soil and climate are adapted to the crop?
3. What varieties of alfalfa are best suited to your section? Why?
4. Discuss the effect of various factors on the composition and value of alfalfa hay.
5. What effect does the stage of maturity at which alfalfa is cut for hay have on its longevity?
6. What are *alfalfa meal, alfalfa leaf meal,* and *alfalfa stem meal?*
7. Discuss the value and use of alfalfa hay for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses; (e) swine; (f) poultry.
8. What is the relative value of alfalfa meal

when added to the concentrate mixture for dairy cows fed plenty of good roughage?
9. Discuss the use of alfalfa for pasture.
10. Discuss the use of alfalfa for silage; as a soiling crop.
11. Why are alfalfa-grass mixtures preferable to pure alfalfa in many regions?
12. Compare the merits of red clover and alfalfa as hay crops for your locality.
13. At what stage of maturity should red clover be cut for hay?
14. Discuss the use of red clover for pasture; for silage; as a soiling crop.
15. Of what importance are the following in your locality: (a) Mammoth clover; (b) alsike clover; (c) white clover; (e) Ladino clover; (f) crimson clover?
16. Discuss the use of sweet clover for pasture and for hay.
17. What other clovers are grown in your area?
18. What is the value of soybean hay for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry?
19. Should soybeans or soybean combinations be raised for silage in your area?
20. Discuss the use of soybeans as a soiling crop and for pasture.
21. Discuss the value as forage crops of any of the following that are important in your state: (a) Annual lespedeza; (b) sericea lespedeza; (c) cowpeas.
22. Which of the other legumes discussed in this chapter are grown in your state, and how are they used?
23. How can legume straw or chaff be used best in stock feeding?

REFERENCES

1. Willard, Ohio Bul. 497; Bachtell and Allen, Ohio Bul. 538; Willard, Thatcher, and Cutler, Ohio Bul. 540.
2. Lyon, N.Y. (Cornell) Bul. 645.
3. Armsby, The Nutrition of Farm Animals, p. 660; Forbes and Kriss, Penn., Jour. Agr. Res., 31, 1925, pp. 1083–1099; Forbes and Kriss, Penn., Jour. Agr. Res., 34, 1927, pp. 785–796; Mitchell, Kammlade, and Hamilton, Ill. Bul. 317.
4. Cunningham, Ariz. Bul. 155.
5. Dawson, Kopland, and Graves, U.S.D.A. Tech. Bul. 739.
6. Salmon, Swanson, and McCampbell, Kan. Tech. Bul. 15.
7. Gordon, Dawson, Hosterman, and Moore, U.S.D.A., Jour. Dairy Sci., 35, 1952, pp. 755–763.
8. Stanley and Walker, Ariz. Bul. 170; Ariz. Rpt. 1942; Headley, Nev. Bul. 161; Neale and Bell, New Mex. Bul. 309; Knox and Neale, New Mex. Bul. 310; Neale and Koger, New Mex. Bul. 335, Ore. Bul. 401; Carroll, Utah Bul. 126; Hackedorn, Singleton, and Sotola, Wash. Bul. 351; Wyo. Rpts. 54, 55.
9. Shepherd et al., U.S.D.A. Tech. Bul. 1079; Horton and Harshbarger, Ill., Jour. Dairy Sci., 34, 1951, p. 491.
10. Assoc. of Amer. Feed Control Officials, Official Publication, 1955.
11. Norton, N.Y., Jour. Dairy Sci., 29, 1946, pp. 546–547; Morrison and Rupel, Wis. Bul. 496; Rupel, Wis. Bul. 404.
12. Lindsey, Mass. Rpt. 1909, Part II, pp. 158–166; Snyder, Nebr. Bul. 164; Mairs, Penn. Bul. 80; Hills, Vt. Rpt. 1906; Rothwell, Canada Expt. Farms, Anim. Husb. Div. Rpt. 1924.
13. Seath, Bastin, Lassiter, and Elliott, Ky. Bul. 607; see also: Porter et al., Conn. and U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 1140–1149.
14. Brown, Willard, Hamilton, and Read, Wyo. Bul. 321.
15. Warren et al., Conn. and U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 523–530; Fountaine, Kan. Rpt. 1950–1952.
16. Kuhlman and Cave, Okla., Jour. Anim. Sci., 7, 1948, pp. 537–538; Okla. Farm Res. Flashes, May, 1953.
17. Neale and Koger, New Mex. Bul. 335
18. Edmonds and Kammlade, Ill. Bul. 238; Obrecht, Ill. Bul. 150; Caine, Iowa Cir. 130; McCampbell, Kan. Bul. 186; Gramlich, Nebr. Exten. Bul. 28; Carroll, Utah Cir. 43; Faville, Wyo. Bul. 98.
19. Loeffel, Nebr., mimeo. rpt.; Robison, Ohio Bul. 488; Kuhlman and Wilson, S.D. Bul. 216; Morrison, Bohstedt, and Fargo, Wis., mimeo. rpts.; see also: Nordby, Id. Cir. 56; Weber, Anderson, and Marston, Kan. Cir. 138; Ferrin and McCarty, Minn., mimeo. rpt.; Weaver, Mo. Bul. 272; Snyder, Nebr. Bul. 147; Gramlich and Jenkins, Nebr. Bul. 175; Loeffel, Nebr., mimeo. rpts.; Thompson, Okla. Rpt. 1930–32.
20. Wheeler, Kan. Bul. 192; McCampbell, Kan. Cir. 78; Snyder, Nebr. Bul. 147; Gramlich and Jenkins, Nebr. Bul. 175; Loeffel, Nebr., mimeo rpts.
21. Freeman, Mich. Quar. Bul. 17, 1935, No. 3.
22. Joseph, Mont. Bul. 169; Vinke and Bergstedt, Mont. Bul. 284; Carroll, Utah Bul. 192; Sinclair, Univ. of Alberta, Canada, mimeo. rpt.
23. Lepkovsky, Schaeleff, Peterson, and Perry, Cal., Poultry Sci., 29, 1950, pp. 208–213; Peterson, Cal., Jour. Nutr., 42, 1950, pp. 597–607; Wilgus and Madsen, Colo., Poultry Sci., 33, 1954, pp. 448–459; Hansen et al., Ill., Jour. Nutr., 49, 1953, pp. 453–464; Ayala and Johnson, Iowa, Poultry Sci., 33, 1951, pp. 893–899; Borchers, Ackerson, and Mussehl, Nebr. Rpt. 63; Kodras, Cooney, and Butts, Ore., Poultry Sci., 30, 1951, pp. 280–292; Texas Rpt. 1950; German and Couch, Texas, Poultry Sci., 29, 1950, pp. 841–845; Mangelson, Draper, Greenwood, and Crandall, Utah, Poultry Sci., 28, 1949, pp. 603–609; Hewang and Bird, U.S.D.A., Poultry Sci., 33, 1954, pp. 239–241.
24. Alder, Utah Farm and Home Res., 10, 1949, No. 3.
25. Evvard, Iowa Bul. 136 and Iowa Cir. 53; Evvard, Amer. Soc. Anim. Prod., Proc. 1913; Edwards, Mich. Spec. Bul. 199; Robison, Ohio Bul. 552; Morrison and Bohstedt, Wis. Bul. 323; Morrison, Fargo, and Brant, Wis. Cir. 213.
26. Gordon, Moore, and Hosterman, U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 1116–1122.

27. Hilton, Wilbur, and Mott, Ind. Cir. 290.
28. Summarized by Thorne, Ohio Bimo. Bul. 167.
29. Wilsie and Hollowell, Iowa Res. Bul. 357; Willard, Cutler, and McLaughlin, Ohio Bimo. Bul. 167; Pollock and Hosterman, U.S.D.A. Farmers' Bul. 1770.
30. Hayden, Ohio Buls. 327, 631; Bechdel, Penn. Bul. 188.
31. Skinner and King, Ind. Buls. 178, 183, 191, 206, 245; Evvard, Culbertson, Wallace, and Hammond, Iowa Bul. 253; Fuller and Morrison, Wis. Buls. 362, 373, 388.
32. Skinner and King, Ind. Buls. 179, 184, 192, 202; Ky. Rpts. 1941, 1942, 1944; Carmichael and Hammond, Ohio Bul. 245; Humphrey and Kleinheinz, Wis., information to the author.
33. Obrecht, Ill. Bul. 150.
34. Morrison, Fargo, and Thomas, Wis. Bul. 388; Robison, Ohio Bul. 488.
35. Evvard, Iowa Bul. 136; Robison, Ohio Bul. 552; Morrison and Bohstedt, Wis. Bul. 323 and mimeo. rpts.; Morrison, Fargo, and Brant, Wis. Cir. 213.
36. Owen, La. Bul. 479.
37. N.J. Rpt. 1948; Winter, Chamberlin, and Burkhart, Ohio Farm and Home Res. 277.
38. Vestal and Mott, Ind. Rpts. 63, 65; Ky. Rpt. 1949; Vandernoot, N.J. Rpt. 1949; Oliver, Ore. Cir. of Inf. 490; Thomas, Kincaid, and Taylor, Va. Rpt. 1950–53.
39. Loosli, Krukovsky, Lofgreen, and Musgrave, N.Y., Jour. Dairy Sci., 33, 1950, pp. 228–236.
40. Morrison, Sheuring, Marden, and Deal, Ga., Jour. Dairy Sci., 35, 1952, p. 502.
41. Skoglund and Tomhave, Del. Cir. 13; Culton, Smyth, and Plummer, Maine Bul. 449.
42. Helm, Mo. Cir. 323.
43. Olson, S.D. Rpt. 1940.
44. Mortimer and Rupel, Wis. Bul. 410.
45. Ensminger, Heineman, and Cunha, Wash. Bul. 470; Law, Schwendiman, and Ensminger, Wash. Bul. 509.
46. Rice, Ill. Bul. 247; Evvard, Iowa Bul. 136; Weber, Anderson, and Marston, Kan. Cir. 138; Ferrin and McCarty, Minn., mimeo. rpt.; Arnett and Joseph, Mont. Bul. 128; Nebr. Rpt. 1926; Shepperd, N.D. Bul. 174; Robison, Ohio Bul. 552; S.D. Rpt. 1930; Smith, Wash. Bul. 187; Morrison and Bohstedt, Wis. Bul. 323; Morrison, Fargo, and Brant, Wis. Cir. 213.
47. Iowa Rpt. 1924; Kan. Rpt. 1926–28; Paterson and Marston, Kan. Cir. 109; Reed and Marston, Kan. Cir. 123; Aubel and Connell, Kan. Rpt. 1932–34; Kiser and Peters, Minn. Bul. 261; Jordan and Peters, Minn. Bul. 306; Olson, S.D. Rpt. 1933; Wilson, S.D. Buls. 160, 143; Hackedorn, Bean, and Sotola, Wash. Buls. 170, 185; McCall and Hackedorn, Wash. Bul. 342; Hackedorn, Singleton, and Sotola, Wash. Bul. 351; McDonald, Wash. Buls. 354, 368, 394; Sotola and McDonald, Wash. Bul. 384.
48. Stahmann, Huebner, and Link, Wis., Jour. Biol. Chem., 138, 1941, pp. 513–527.
49. Roderick and Schalk, N.D. Bul. 250; Schofield, Jour. Amer. Vet. Med. Assoc., 64, 1924, pp. 553–575; Fitch, Amer. Soc. Anim. Prod., Proc. 1923; Crosby and Kephart, U.S.D.A. Farmers' Bul. 1653; Crosby, U.S.D.A. Tech. Bul. 380; White, Greenshields, and Chubaty, Canadian Jour. Agr. Sci., 34, 1954, pp. 601–606.
50. Hazlewood, Tenn. Rpt. 1940.
51. Branton, Seath, and Rusoff, La. Rpts. 1942, 1943; Miss. Rpt. 1942.
52. Glasscock, Cunha, and Pearson, Fla. Cir. S-9.
53. Marshall and Dix Arnold, Fla. Rpt. 1953, Fla. Bul. 542.
54. Burton et al., Ga. Coastal Plain Bul. 47.
55. Ewing, Tenn. Cir. 104.
56. Semple, Vinall, Enlow, and Woodward, U.S.D.A. Misc. Pub. 194; Harper, Elder, and Ross, Okla. Bul. B-348.
57. Hollowell, U.S.D.A. Farmers' Bul. 1929; Haddon, La. Bul. 441.
58. Love and Sumner, Cal. Cir. 407; Love. Cal., Jour. Agr. and Food Chem., 3, 1955, pp. 308–309.
59. Eslick and Dickey, Colo. Farm Bul., 6, 1944, No. 1.
60. Burlison, VanDoren, and Hackleman, Ill. Bul. 462; Dyas, Iowa Bul. P 30; Penn. Bul. 502.
61. Nevens, Ill. Rpts. 1931, 1932, 1937; Hilton, Wilbur, and Epple, Ind. Bul. 346; Good, Ky. Bul. 435; Ragsdale, Herman, and Snyder, Mo. Bul. 457; Mo. Bul. 477.
62. Nevens, Ill. Cir. 369; Ill. Bul. 310; Caldwell, Ind. Bul. 203; Cannon and Johnston, Iowa Exten. Bul. 196; Fitch, Kan. Rpts. 1926–28, 1928–30, 1930–32; Moore and Cowsert, Miss. Bul. 235; Hayden, Ohio Bul. 470; Bechdel, Penn. Bul. 201; Olson, S.D. Buls. 201, 215; Anthony and Henderson, West Va. Bul. 181; Henderson, West Va. Bul. 244; Morrison, Savage, and Hulce, Wis. Bul. 362; Morrison, Humphrey, and Rupel, Wis. Buls. 373, 388.
63. Morrison, Humphrey, and Rupel, Wis. Buls. 373, 388; Rupel, Roche, and Bohstedt, Wis. Res. Bul. 102.
64. Schaefer, Minn. Bul. 239; see also: Bierman, Md. Bul. 277.
65. Dvorachek, Ark. Bul. 203; Rusk and Snapp, Ill. Rpts. 1933, 1935; Skinner and King, Ind. Buls. 314, 330, 396; Good, Ky. Rpts. 1933, 1934, Ky. Bul. 435; Means, Miss. Rpt. 1932; Trowbridge, Mo., mimeo. rpt.; Bohstedt, Ohio Bimo. Bul. 105–106; McComas, Hazen, and Comfort, U.S.D.A. Cir. 629.
66. N.C. Rpt. 1944; see also: Thomas, Mochrie, Smart, and Matrone, N.C., Jour. Anim. Sci., 14, 1955, p. 1258.
67. Hunt, Md. Bul. 378; see also: Kendall and Hays., Ill., Jour. Dairy Sci., 35, 1952, p. 498; Kendall, Hays, and Rolleri, Ill., Jour. Anim. Sci., 13, 1954, pp. 859–866.
68. Kammlade, Ill. Buls. 260, 338; Skinner and King, Ind. Buls. 282, 296; Harper, Ind. Buls. 304, 333; Evvard, Culbertson, Hammond, and Henness, Iowa Bul. 234.
69. Templeton, Miss. Bul. 270.
70. Morrison, Fargo, and Thomas, Wis. Bul. 488; Dvorachek, Ark. Buls. 181, 203, 215.
71. Kennard and Chamberlin, Ohio Bul. 579.
72. Dvorachek, Ark. Bul. 196; Iowa Rpts. 1924, 1925; Bechdel, Penn. Bul. 178; Wise, LaMaster, and Mitchell, S.C. Rpt. 1943.
73. Skinner and Starr, Ind. Bul. 220; Skinner and Vestal, Ind. Bul. 240; Skinner and King. Ind. Buls. 249, 255; Goodell, Miss. Bul. 222; Quesenberry, U.S.D.A. Bul. 1318; U.S.D.A. Cir. 65.
74. Cullison, Miss. Farm. Res., 5, 1942, No. 4; Miss. Rpts. 1941, 1942; see also: Cromer and Bechdel, Penn. Bul. 464.
75. Ky. Rpts. 1949, 1950.
76. Becker et al., Fla. Bul. 255.
77. Weaver, Mo. Bul. 247; Ohio Bul. 552.
78. Godbey, Kyzer, and Clyburn, S.C. Bul. 289;

Tomhave, Del. Bul. 179; Carmichael, Md. Bul. 376; Miss. Sta., mimeo. rpt.

79. Gray, Ridgeway, and Eudaly, Ala. Bul. 154; Good and Smith, Ky. Bul. 201; Bedenbaugh, Miss. Buls. 283, 410; Hostetler, N.C., mimeo. rpt.; N.C. Rpts. 1938–40, 1941; Godbey, S.C. Bul. 274.
80. Brown and Helm, Mo. Bul. 486.
81. Swanson and Herman, Mo. Res. Bul. 372; Swanson and Herman, Mo., Jour. Dairy Sci., 27, 1944, pp. 263–268; Ky. Rpt. 1943; Rusoff, Seath, and Miller, La., Jour. Dairy Sci., 28, 1945, pp. 869–872; 29, 1946, pp. 613–615.
82. Herman, Swanson, and Ragsdale, Mo., Jour. Dairy Sci., 27, 1944, pp. 626–627; Herman, Graham, and Bower, Mo. Res. Bul. 532.
83. Ruby, Ray, and Mobry, Ark. Bul. 515; Ratcliff et al., Ark. Bul. 532; Nevens, Ill., Jour. Dairy Sci., 18, 1935, pp. 593–598; Rusk and Snapp, Ill. Rpts. 1935, 1936; Kammlade, Ill. Rpts. 1936, 1938–47; Ky. Rpts. 1938, 1940; Moore and Cowsert, Miss. Bul. 235; Miss. Rpt. 1940; Trowbridge, Comfort, and Hazen, Mo. Bul. 387; Ragsdale and Herman, Mo. Bul. 413; Grinnells, N.C. Bul. 302; Holdaway, Ellett, Eheart, and Pratt. Va. Bul. 305; McComas, Hazen, and Comfort, U.S.D.A. Cir. 629; Van Horn et al., U.S.D.A. and Tenn., Jour. Dairy Sci., 35, 1952, pp. 559–565.
84. Ringrose and Morgan, S.C. Rpts. 1940, 1941; Parker, McSpadden, and Weathers, Tenn. Rpt. 1940.
85. Muhrer and Gentry, Mo. Res. Bul. 429.
86. Henson and Hanson, U.S.D.A. Agr. Res., 3, 1954, No. 3.
87. Ratcliff et al., Ark. Bul. 532; Massey, Ga. Bul. 200; Massey and Buice, Ga. Bul. 236; Ga. Rpt. 1949; Ky. Rpts. 1935, 1936, 1938, 1940; Grinnells, N.C. Rpt. 1935; Mooers and Ogden, Tenn. Bul. 1954; Chance, Tenn. Rpt. 1939; Vandiver, Tenn. Rpt. 1943; Holdaway, Ellett, Eheart, and Pratt, Va. Bul. 305; Pieters, U.S.D.A. Cir. 534; Clark, Frey, and Hyland, Jour. Agr. Res., 58, 1939, pp. 131–139.
88. Hawkins, Ala., Jour. Dairy Sci., 38, 1955, pp. 237–243.
89. Grimes, Ala., mimeo. rpt.; Ga. Coastal Plain Rpt. 1938; N.C. Rpt. 1944; Marshall and LaMaster, S.C. Rpt. 60; King and LaMaster, S.C. Rpt. 62; Wylie and Hinton, Tenn., Jour. Dairy Sci., 18, 1835, p. 443; Chance, Tenn. Rpt. 1939; Henson, Hein, Hazen, and Black, U.S.D.A., Jour. Anim. Sci., 2, 1943, pp. 314–320.
90. Shuey, Tenn. Rpt. 1940; Vandiver, Tenn. Rpt. 1943; Hinton and Wylie, Tenn., Jour. Dairy Sci., 23, 1940, pp. 564–565.
91. Duggar, Ala. Bul. 123; Dvorachek, Ark. 203; Wing, Ga. Bul. 49; Lane, N.J. Bul. 174.
92. Edwards and Massey, Ga. Bul. 184; Waters, Mo. Bul. 76.
93. Reed and Marston, Kan. Cir. 123; McDonald and Malone, Okla. Bul. 78; Darlow, Okla. Buls. 196, 213.
94. Burkett, N.C. Bul. 189.
95. Dvorachek, Ark. Buls. 181, 203, 215.
96. Lantow, Black, and Burnham, New Mex. Bul. 156; Black, Lantow, and Burnham, U.S.D.A. Tech. Bul. 30.
97. Ronning, Kuhlman, Cave, and Gallup, Okla. Bul. B-403.
98. Dvorachek, Ark. Bul. 221.
99. Jacobs, Okla. (Panhandle) Buls. 26, 50.
100. Richards, Del., Jour. Dairy Sci., 37, 1954, p. 658; see also: Smith and Davis, Cal. Cir. 411.
101. Driggers, Dennison, Davis, and Mehrhof, Fla. Cir. S-30.
102. Loosli, Krukovsky, Lofgreen, and Musgrave, N.Y., Jour. Dairy Sci., 33, 1950, pp. 228–242.
103. Pierre and Jackobs, Ill. Cir. 725; Mott, Smith, McVey, and Beeson, Ind. Bul. 581; Hughes and School, Iowa Farm Sci., 5, 1951, No. 9; Mont. Rpts. 50–59; Kardos and Blood, N.H. Bul. 402; Jones, New Mex. Press Bul. 1128; MacDonald, N.Y. (Cornell) Exten. Bul. 797; Haynes and Davis, Ohio Bul. 725; Ore. Bul. 508; Carnahan and Fortmann, Penn. Bul. 553; Varney, Vt., Better Crops with Plant Food, May, 1953.
104. Md. Bul. A-67; Worzella et al., S.D. Bul. 427; R.I. Rpt. 61; Va. Rpt. 1950–53; Veatch, West Va. Bul. 343.
105. Wallace and Killinger, Fla. Cir. S-49; N.C. Rpt. 1946; Howell, Ore. Bul. 456.
106. Davis and Singer, Fla. Rpts. 1950, 1951; Piercey and Rusoff, La. Cir. 36.
107. McKee, Ritchey, Stephens, and Johnson, U.S.D.A. Farmers' Bul. 1980.
108. Tracy, U.S.D.A. Farmers' Bul. 1125.
109. Squibb and Love, Guatemala, Jour. Anim. Sci., 8, 1949, p. 630; Squibb and Wyld, Poultry Sci., 29, 1950, pp. 586–588.
110. Ripperton, Hawaii Rpt. 1948–50.
111. Daniel and Ensminger, Wash. Pop. Bul. 179; Daniel et al., Wash., Jour. Anim. Sci., 5, 1946, pp. 80–86; Hodgson and Knott, Wash., Jour. Dairy Sci., 19, 1936, pp. 531–534.
112. Brooks and Harvey, Texas Cir. 126.
113. Hodges, Kirk, and Jones, Fla. Rpt. 1952; Fla. Rpt. 1951; La. Rpts. 1948, 1949.
114. Nordfeldt, Henke, Willers, and Cross, Hawaii Tech. Bul. 15.
115. Henke and Morita, Hawaii Cir. 44; Takahashi and Ripperton, Hawaii Bul. 100; Henke, Hawaii Rpt. 1950–52; see also: Farinas, Philippine Jour. Anim. Indus., 12, 1951, pp. 64–84.
116. Sturkie and Grimes, Ala. Cir. 83; Gelpi, Staples, and Seath, La. Rpt. 1942; King and LaMaster, S.C. Rpt. 62.
117. Grimes, Ala. Rpt. 1942–44; Ga. Coastal Plain Bul. 40.
118. Grimes, Ala. Rpt. 1942–44.
119. Cottier and King, Ala. Rpt. 1941.
120. Whitehurst, Kirk, and Warner, Fla. Rpt. 1941; McCormick, Glasscock, and Warner, Fla. Rpt. 1942; Massey and Fisher, Ga. Cir. 144; Miss. Rpt. 1942; Cullison and Holmes, Miss. Farm. Res., 5, 1942, No. 6.
121. King and LaMaster, S.C., Jour. Dairy Sci., 33, 1950, p. 389.
122. Ga. Rpt. 1945; Polk and Gieger, Miss. Bul. 414.
123. Telford and Childers, U.S.D.A., Agr. in Americas, 5, 1945, pp. 210–211.
124. Burton, Shepherd, and DeVane, Ga. Coastal Plain Cir. 23; McKee and Ritchey, U.S.D.A. Farmers' Bul. 1946.
125. Wilson, S.D. Bul. 143; Quayle, Wy. Rpts. 1929, 1930.
126. Iddings and Hickman, Id., information to the author; Huffman, Dexter, and Duncan, Mich. Quar. Bul., 36, 1954, No. 3; Bechdel, Penn. Buls. 176, 178; Potter and Dean, Ore. Bul. 198; Faville, Wyo. Bul. 109; Hays, Wyo. Bul. 130; U.S.D.A., Rpt. of Chief of Bureau Dairy Industry, 1951.

127. Mont. Rpt. 1923; Robison, Ohio Bul. 552; Ore. Rpts. 1920–22, 1922–24; McCarty and Grimes, Penn. Bul. 270; Hackedorn, Wash. Bul. 158; Morrison and Bohstedt, Wis. Bul. 323.
128. Salmon and Sewell, Ala. Rpt. 1936.
129. Newson and Cross, Colo. Bul. 474.
130. Thompson, N.D. Bul. 217; Gongwer and Hickman, Id. Bul. 125; see also: Osland and Morton, Colo. Bul. 381.
131. Colo. Rpt. 1943; Tretsven, Mont. Bul. 317; Richards, Ore. Bul. 370; Lindley and Ensminger, Wash. Sta. Cir. 154; Schneider, Luce, and Goodwin, Wash., Jour. Anim. Sci., 12, 1953, pp. 930–931; Rupel, Roche, and Bohstedt, Wis. Bul. 420; Bohstedt, Grummer, and Pope, Wis. Bul. 463.
132. Bird, Md., Poultry Sci., 23, 1944, pp. 76–77; Cunha, Rasmussen, Ensminger, and Roberts, Wash. Sta. Cir. 65.
133. Ga. Rpts. 1942, 1943, 1944, 1946, 1949; Grinnells and Moore, N.C. Bul. 312; Ronning, Kuhlman, Cave, and Gallup, Okla. Bul. B-400; Pratt and Eheart, Va. Bul. 366.
134. Grimes, Ala. Rpts. 1937, 1939; Shealy and Gratz, Fla. Bul. 320; Ga. Rpt. 1949; Massey and Fisher, Ga. Cir. 144; Massey, Ga. Bul. 211; Ga. Coastal Plain Buls. 36, 40, 49; Langley, Jones, and McCullough, Texas Progress Rpt. 1396.
135. Rensburg, Farming in S. Africa, 12, 1937, pp. 197, 202.
136. Pratt and Eheart, Va. Bul. 366; Jensen, Peterson, and Herbert, N.C. Rpt. 1947.
137. Grinnells, N.C. Rpt. 1938.
138. Ga. Rpts. 1940, 1942, 1943, 1944.
139. Takahashi and Ripperton, Hawaii Bul. 100.
140. Engel and Salmon, Ala. Rpts. 60–61; Burton, Ga. Coastal Plain Bul. 47; Dupuy and Lee, La. Rpt. 1952; Miss. Rpt. 1949.
141. Ga. Coastal Plain Bul. 42.
142. Gray, Summers, and Shook, Ala. Bul. 168; Templeton, Ferguson, and Gibbens, Ala. Bul. 198; S.C. Rpt. 1923.
143. Ore. Buls. 350, 359.
144. Moore, Miss. Farm. Res., 6, 1943, No. 12; see also: Burton, Parham, Southwell, and Stephens, Ga. Coastal Plain Bul. 47.
145. Jones, Ore. Bul. 194.
146. Rothwell, Can. Expt. Farms, Anim. Husb. Div., Rpts. 1922, 1924.
147. Rinehart, Hickman, and Johnson, Id. Bul. 194; see also: Hodgson, et al., Id. Bul. 272.
148. Id. Bul. 229; Richards, Ore. Bul. 370; Maynard, Esplin, and Boswell, Utah Bul. 238; see also: Cox and Sloan, Kan. Rpt. 1940–42; Cox and Erhart, Kan. Livestock Feeders' Day Rpt., 1949.
149. Miller, Cal. Rpt. 1923; Morton, Osland, and Brandon, Colo. Press Bul. 80; Mumford, Mich. Bul. 136; Vinke and Hanson, Mont., mimeo. rpt.; Quayle, Wyo. Bul. 191; Ingraham, Wyo. Bul. 247.
150. Nevens, Ill., Jour. Dairy Sci., 17, 1934, pp. 671–674.
151. Hackedorn, Wash. Bul. 155; Hackedorn and Sotola, Wash. Bul. 157; McCall and Hackedorn, Wash. Bul. 352; Ensminger, Warwick, and Cunha, Wash. Bul. 455; Ensminger and Heineman, Wash. Bul. 470.
152. Nevens, Ill. Cir. 369.
153. Kammlade and Mackey, Ill. Bul. 260; see also: Carmichael, Ohio Bul. 245; Beeson, Perry, Nickel, and McVey, Ind., Mimeo. Rpt. AH 59.

CHAPTER XVII

INDIAN CORN AND THE SORGHUMS FOR FORAGE

I. Indian Corn

514. Indian corn excels as a forage crop.—Indian corn (*Zea mays*) is well called king among our crops in the United States, for corn far excels other crops both in acreage and in value. Our corn is raised chiefly for grain, but it is also our main silage crop, and a large acreage is grown for hogging down, for fodder, or for grazing. When corn is grown for grain, the stover left after husking can be an important winter feed for stock.

With the acreage restrictions that have been in force, the acreage of corn harvested in the country has recently been about 80,000,000 acres. Over 85 per cent of our corn is grown for grain, only 7 to 8 per cent being raised for silage and 4 to 5 per cent for hogging down, fodder, or grazing.

When the entire corn plant is used for forage, as in growing it for silage, it excels all other forage crops in average yield of dry matter and of digestible nutrients per acre. In these respects it even slightly surpasses alfalfa, the queen of the legume roughages. (**450**)

Though it flourishes best in the corn belt, corn is an exceedingly adaptable crop, and it is raised for grain or for forage on more than two-thirds of all the farms in the United States. Corn is a heat-loving plant and does not thrive if the nights are cool. However, early-maturing, short varieties have been developed that will usually ripen in the northern-most states.

If corn is planted rather thickly, a heavy yield of forage is secured, with but little grain. On the other hand, when the plants are grown the proper distance apart, there is a large yield of grain, with forage as a secondary product. As is pointed out later in the discussion of corn as a grain, it ranks first among the cereals in feeding value and also in yield of grain per acre. (**681**) In addition, the corn stover is worth much more per acre for stock feeding than the straw from the small grains.

515. Corn fodder; shock corn; corn stover.—In discussing the uses of corn as a forage crop, it is important to have definitely in mind just what is meant by the terms used in speaking of corn forage.

The terms *corn fodder* and *fodder corn* are commonly used for corn plants, either fresh or cured, which have been grown primarily for forage, with all of the ears, if any, originally produced. *Shock corn* (sometimes called bundle corn) means corn grown primarily for grain, but which is fed without husking. Sometimes shock corn is also called corn fodder.

Corn stover is the term applied to cured shock corn from which the ears have been removed. Corn stover is often called "corn stalks," but this term is misleading, for the greater feeding value is in the leaves and not in the stalks.

The terms fodder and stover are also applied to such crops as the sorghums. For example, kafir forage is called either kafir fodder or else kafir stover, depending on whether or not the heads have been removed.

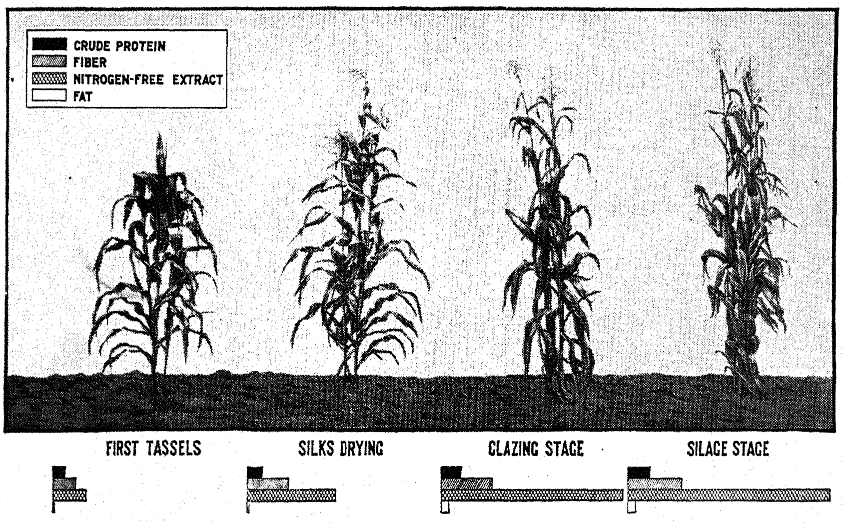
516. Thickness of planting.—The greatest yield of sound corn grain is secured when the kernels are planted far enough apart so all the plants produce full-sized ears. A common rate for dent corn on good soil in the corn belt was formerly 10,000 to 12,000 kernels per acre. In recent tests hybrid corn has yielded best on well-fertilized soil with as many as 16,000 plants per acre. On less fertile soil or where rainfall is scanty,

the rate should be less. Early-maturing, short varieties should be planted somewhat more thickly than larger varieties.

Under favorable conditions the largest yields of total dry matter and of digestible nutrients are secured from corn planted more thickly than when grown for grain, but the yield of grain will then be much less. If the crop is raised for silage to be fed to stock that need a liberal allowance of concentrates (such as milk cows or fattening cattle or sheep), it is best to plant it at a rate which will produce a large proportion of ears. However, the crop even then is usually planted a little more thickly than when it is raised for grain.

If the silage is to be fed to beef breeding cows not nursing calves or to yearling or older beef cattle which are being carried through the winter to be fattened on grass the following summer, sometimes the corn is planted so thickly that the proportion of ears is small. This is because such cattle do not need much grain. Another method occasionally used for such stock is to feed corn-stover silage, or to husk out some of the ear corn before the crop is ensiled.

517. Nutrients lost when crop is harvested too early.—Experiments in which corn plants have been analyzed at various stages of growth have shown that there is a heavy loss of nutrients when the crop is harvested too early. At the milk stage, when corn is sometimes cut for silage, the crop has the greatest green weight. However, an acre of corn then has only two-thirds as much dry matter as when the kernels have ripened. There is even greater difference in the amount of total digestible nutrients or of net energy per acre, because of the great storage of starch in the corn kernels as they mature.



NUTRIENTS IN CORN PLANTS AT VARIOUS STAGES

The shaded areas in the legend represent the amounts of crude protein, fiber, nitrogen-free extract, and fat in corn plants at various stages. Note especially the large storage of nitrogen-free extract as the crop matures. (From Indiana Station.)

In Indiana experiments it was found that from the milk stage to the date when the corn was ready to shock (a period of less than a month), there was a gain per acre of 2,500 lbs. nitrogen-free extract, over a ton of which was starch.[1] Nearly all of this storage had taken place by the silage stage, when the kernels were dented.

The chief storage of fat also occurs after the milk stage, when the germs in the kernels are developing. On the other hand, the increase in protein, fiber, and

mineral matter is most rapid in the earlier stages, when the leaves and stalks are growing fastest.

518. Composition of corn forage.—Like corn grain, corn forage is high in carbohydrates and low in protein. Well-dried corn fodder has only about half as much protein as does alfalfa hay, and corn stover has even less.

When the corn crop is stricken with drouth, so that no ears develop and the plants are killed, the forage will have a considerably higher percentage of protein than normal, but the total yield of nutrients will be low. Likewise, corn harvested in the milk stage or before will contain a higher percentage of protein, on the dry basis, than more mature forage. However, such immature forage is watery and low in total nutrients.

Corn forage resembles grass hay in content of both calcium and phosphorus. Corn fodder or silage grown on soil well supplied with calcium is fair in calcium content, having 0.25 per cent or more on the dry basis. Corn stover is higher than corn fodder in calcium. Where the soil is deficient in calcium, the corn forage will be low in this mineral.

Corn fodder and corn silage are rather low in phosphorus. The percentage depends somewhat on the phosphorus supply in the soil, and corn forage grown on phosphorus-poor land will be deficient in this mineral. Corn stover is very low in phosphorus, as most of the phosphorus is in the grain.

Green corn forage, even from white corn, is high in vitamin A value. This is because the green corn leaves and stalks contain a greater total amount of carotene than the grain, even in the case of yellow corn. The vitamin A value of dry corn fodder will vary widely, depending on whether the leaves and stalks were green when the crop was harvested, and on how well it was cured.

Differing from most other green, growing crops, green corn forage may supply considerable vitamin D, if not harvested before the dent stage. Michigan studies, mentioned previously, show that the leaves which are still green have practically no vitamin D, but the dried parts—tassels, silks, husks, and any dried leaves—are rich in the vitamin. (**204**) Corn silage harvested at this stage therefore furnishes much more vitamin D than does hay-crop silage, which may have little or none. In the Michigan investigation corn silage supplied sufficient vitamin D to meet the needs of dairy cows or of yearling heifers.[2]

Even when grown for grain, an appreciable part of the feeding value of the corn crop is in the stover.[3] The stover will have nearly one-half of the dry matter and about one-fourth of the digestible protein and net energy of the entire crop. This shows the loss of feeding value that occurs when corn stover is not utilized.

519. Corn silage.—Wherever corn thrives, it is an ideal silage crop. For this reason, by far the greater part of all the silage in this country is made from corn. If green corn forage is harvested at the proper stage of growth and is ensiled with ordinary care, it almost always makes excellent silage. The cut forage packs well in the silo, and it contains sufficient sugar so that enough acid is produced in the silage to keep it from spoiling. (**425**)

The fact that corn almost invariably makes good silage is an important point to consider in deciding whether to use corn or hay crops, such as alfalfa, for silage. Good silage can generally be made from hay crops, if care is taken to use one of the special methods which have been described earlier. (**428–435**) However, sometimes the hay-crop silage is decidedly inferior in quality to the usual grade of corn silage.

The yield of silage per acre varies widely with the soil and season. A 50-bushel crop of corn should make from 8 to 10 tons of silage, depending on the size and leafiness of the plants. The average yield of corn grown for silage in this country is about 8 tons per acre, but 10 tons or more are readily secured when the crop is grown on fertile land well adapted to corn.

Corn makes the best silage if cut when the kernels have reached the glazing stage, but while most of the leaves

are still green. At the glazing stage the dent varieties will be well dented. Ensiling the corn should not be delayed longer, or the corn will become too mature to make the most palatable silage, and it may mold unless water is added as the cut forage is ensiled. On the other hand, if ensiled too early, very sour silage is produced. Still more important, there is a great waste of nutrients, for the chief storage of starch will not have occurred.

The vitamin A value of the silage is much lower if the crop is ensiled when the leaves have begun to turn yellow. In a Wisconsin test early-dent-stage corn silage had 3 times as much carotene as late-harvested silage.[4] When cows were changed from the more mature silage to that made at the early-dent stage, the vitamin A content of their milk was doubled.

The leaves of many of the hybrid corn varieties stay green longer than those of the old open-pollinated varieties. Therefore the best way to tell when hybrid corn is ready for the silo is to examine the ears, or the crop may get too mature for the best silage before one is aware of it.

It has been pointed out previously in this chapter that corn silage harvested at the dent stage may supply enough vitamin D to meet the needs of dairy cows and yearling heifers. (518) It thus differs greatly in this respect from most hay-crop silage.

Although hybrid corn generally has stiffer stalks than many of the old varieties, it is more leafy and has no more fiber and no more lignin (the least valuable carbohydrate). Most of the hybrids usually contain an even larger proportion of ears than the older open-pollinated varieties, and the silage will be fully as palatable and as high in feeding value.[5]

520. Late-maturing vs. earlier corn for silage.—In the North an important question is whether to grow for silage a variety of corn that is early enough to reach the early-dent stage or at least the late-dough stage in the average season, or to grow instead a taller-growing variety that will not usually reach these stages before frost. In most of the experiments on this question, it has been concluded that it is best to grow a variety which will generally reach the early-dent stage or at least the dough stage.[6] When the crop is planted at the proper rate, silage from such a variety will have a large proportion of ears and will therefore have a high nutritive value per ton.

The late varieties will produce a larger tonnage, but the forage will be much more watery. In actual amount of dry matter produced per acre there has usually been but little difference. Silage made from immature corn is apt to be much sourer than that from corn which has at least reached the dough stage, and it may not keep so well. Because of its higher water content and also because it contains little grain and is slightly less digestible, the value per ton will be considerably lower.

Silage from corn harvested at the milk stage or earlier supplies only 60 to 75 per cent as much total digestible nutrients per 100 lbs. as dent-stage silage. For each 100 lbs. of digestible nutrients in the silage, the expense of harvesting and ensiling the crop is therefore much greater in the case of the late varieties, and also much more silo space is required.

Usually the northern stockman who grows plenty of other roughage will wish to fill his silo with richer and more palatable feed than the late-maturing varieties supply. In case he has a very limited amount of corn land and desires to produce the largest possible tonnage of silage, he may decide to grow a late variety and plant it thickly. In feeding such silage, however, it must be remembered that it is low in dry matter. Therefore to prevent lower production of milk or meat, more hay or other dry roughage must be fed with it than in the case of silage from well-eared corn, cut at the dent stage.

It is important not to use for silage a variety that is so early that it will fail to utilize effectively the entire growing season. Such varieties produce much less feed per acre than a variety that just

reaches the desired silage stage in the average season.

If the crop has not reached the proper stage at the usual time for killing frosts to occur, it is best to let it stand until after frost rather than to ensile it when very immature, for satisfactory silage can be made from frosted corn, and the crop may mature to a considerable extent before a severe frost comes. If the crop is killed by frost, it should be ensiled quickly, before the leaves become dry. If the plants dry out before all the crop can be ensiled, enough water should be added as the silo is filled so that the cut forage will pack well.

When corn is ruined by drouth, the silo is the best means of saving all feeding value possible. Water should, of course, be added to the forage as it is ensiled, if it is too dry to pack well.

521. Value of corn silage.—Through the use of corn silage the cost of producing milk and meat can be materially lowered over much of this country. Not only is corn silage excellent for cattle and sheep, but it may be used in a limited way with horses that are idle or at light work. Corn silage is too bulky and fibrous to have much usefulness in feeding swine and poultry. As shown in Chapter XXXV, it gives satisfactory results for wintering bred sows when well supplemented with protein and minerals. However, legume hay is much more efficient for them, because of its high content of protein, vitamins, and calcium. The value and use of corn silage for dairy cattle, beef cattle, and sheep is discussed in later paragraphs.

Corn silage is used most commonly as only part of the roughage for stock, generally being fed in combination with hay or dry fodder. It gives especially good results when fed with legume hay or mixed hay rich in legumes. If corn silage is the only roughage, a calcium supplement, such as ground limestone, should be added to the ration, to ensure a plentiful supply of this mineral.

Silage from well-matured corn supplies slightly more than one-third as much total digestible nutrients per 100 lbs. as does good-quality hay. In experiments with dairy cows, good corn silage has actually been worth 33 to 40 per cent as much per ton as good legume or mixed hay. The feeding value of corn silage for dairy cows therefore agrees well with the amount of digestible nutrients it furnishes.

For fattening cattle and fattening sheep corn silage has an even higher value in comparison with hay. Numerous experiments have shown that for these classes of stock good corn silage is usually worth one-half as much per ton as good legume or mixed hay. This difference in the relative values of silage and hay for dairy cows and for fattening cattle or fattening sheep is somewhat surprising. It may perhaps be explained as follows:

Lambs chew their feed very thoroughly and therefore no corn kernels in the silage escape digestion. In the experiments with fattening cattle, pigs have commonly followed the cattle to salvage any kernels that passed through unchewed. Thus the combination of fattening cattle and pigs completely utilized the grain in the silage. On the other hand, in the case of dairy cows there is an appreciable loss of nutrients because some kernels escape chewing.

This difference in value does not mean that corn silage is an inefficient feed for dairy cows. As is pointed out later, wherever corn thrives, corn silage is usually the most economical succulent feed for winter feeding. The difference merely means that for fattening sheep and also for fattening cattle which are followed by pigs, well-eared corn silage has an even higher actual value than would be estimated from its chemical composition.

In considering the value of corn silage, it should be borne in mind that well-eared corn silage is a combination of roughage and concentrate. Such silage contains 1 pound of dry corn grain in each 7 to 9 lbs. of silage.[7] Therefore, when a dairy cow, for example, eats 30 lbs. a day of such silage, she gets 3 or 4 lbs. of corn grain in the silage. Experiments have shown that the corn grain in silage has the same feeding value as

the same amount of corn fed as the dry grain.[8]

Though corn silage is a very economical feed over much of this country, in some areas either hay as the only roughage or grass silage in combination with hay may be cheaper. (424)

522. Corn silage vs. corn fodder.—There is not a large difference in the amount of nutrients lost when a corn crop is cured as dry fodder under favorable conditions, and when it is ensiled. (426) However, in feeding experiments an acre of corn forage fed as silage has generally had a much greater value than an acre of the same crop fed in the form of dry fodder.

This is doubtless because stock usually reject the butts of the dry corn stalks, even when finely cut, while in silage they are mostly eaten. Moreover, owing to the great palatability of this succulent feed, silage-fed animals consume a larger ration, and more nutrients are hence available for milk or flesh production after meeting the needs for maintenance. Just as important as these advantages is the fact that, like other succulent feeds, silage has a beneficial laxative effect and aids in keeping stock thrifty.

523. Corn silage for dairy cattle.—Throughout the chief dairy districts of the United States, corn is by far the most popular and widely used silage crop for feeding dairy cattle. Not only does corn silage readily provide a uniform supply of high-quality succulent feed for winter, but also it is an excellent supplement to scanty pasture in summer.

A much greater feeding value is secured from an acre of corn when it is ensiled than when it is fed as dry fodder. For example, in an Iowa experiment dairy cows were fed either silage or corn fodder, along with alfalfa hay and a good concentrate mixture.[9] The dry corn fodder was worth only about 45 per cent as much per acre as corn silage. This was largely because of the greater loss in curing the fodder and the waste in feeding it, for the milk yield per cow was only 6 per cent less on the ration containing corn fodder than on the silage ration.

When silage is fed under proper conditions, the flavor or quality of the milk is not injured in the slightest degree. Silage should be fed after milking, the mangers should be cleaned out regularly, silage should not be left scattered on the floor of the stable, and the stable should be properly ventilated.

In a later chapter information is presented on the amounts of corn silage to be fed per head daily to cows under various conditions, and on the use of silage as the only roughage. (1076)

524. Value of corn silage when added to dairy rations.—Numerous experiments have been conducted to determine the effect on milk production when corn silage is added to a ration of hay and concentrates, and to find the relative feeding values per ton of silage and hay.[10] The effect produced by the addition of silage to the ration will depend chiefly on the quality of the hay that is fed and on whether or not there are drinking cups in the stable. When cows have access to water at all times, the addition of silage to a dry ration makes less difference than when they have water less frequently, because silage supplies considerable water.

If silage is added to a ration consisting of a good concentrate mixture and only fair dry roughage, such as ordinary grass hay or dry corn fodder, the milk yield will be considerably increased, even when water is always available. On the other hand, if the dry roughage is legume hay of excellent quality and the cows have access to drinking cups, sometimes there is no increase in milk production and when there is an increase it does not usually exceed 7 to 10 per cent.

In a study by the United States Department of Agriculture of records from cow-testing-association herds, it was found that the average production of cows on silage, legume hay, and grain was 305 lbs. of fat a year; on only legume hay and grain, 299 lbs.; on silage, mixed hay and grain, 279 lbs.; on only mixed hay and grain, 248 lbs.; and on only non-legume hay and grain, 229 lbs.[11] It will be noted that the addition

of silage to a ration of legume hay and grain increased the average production much less than adding it to a ration of poorer hay and grain.

Where the effect of silage feeding has been studied in surveys made in various states on the cost of milk production, it has usually been found that silage-fed herds produced more milk and fat than those fed only dry roughage in winter. However, in some studies the net return has been no larger or even smaller where silage has been fed.

Since a first-class dry ration produces nearly as much milk as when silage is added, one should base his decision as to whether or not to use silage chiefly on the relative cost of nutrients in silage and in hay. He should also consider the other farm management factors which have been discussed in a previous chapter. (**424**)

In the experiments in which silage has been added to a ration of hay and concentrates, it has usually required from 250 to 300 lbs. of well-eared corn silage to equal 100 lbs. of hay in actual feeding value. In these trials good corn silage has therefore been worth 33 to 40 per cent as much per ton as good hay. This is a somewhat lower value than corn silage has for fattening cattle or lambs, as has been mentioned previously.

525. Corn silage for beef cattle.—Silage from well-matured corn, carrying an abundance of ears and consequently a high proportion of corn grain, is the best of all silages for beef cattle. Such silage aids greatly in reducing the amount of grain or other concentrates needed for fattening cattle or for young cattle being carried through the winter. Since corn silage is low in protein, care should be taken to balance the ration with a sufficient amount of protein supplement, when it is one of the chief roughages.

The high value of corn silage for fattening cattle has been proved in numerous experiments. The results of 33 experiments show the effect of adding well-eared corn silage to the already excellent ration of shelled corn, protein supplement, and alfalfa or clover hay.[12] The steers, usually 2-year-olds, received 23.6 lbs. silage, 14.3 lbs. shelled corn, 3.1 lbs. hay, and 2.6 lbs. protein supplement per head daily and gained an average of 2.49 lbs. Those fed no silage gained nearly as rapidly and there was only a trifling difference in selling price in favor of the silage-fed cattle.

The chief advantage from feeding silage was the saving of corn and hay, and the cheapness of the gains. In these many trials each ton of corn silage saved an average of 247 lbs. corn plus 580 lbs. legume hay, but minus 14 lbs. protein supplement. With feeds at representative prices, corn silage was worth fully one-half as much per ton as good legume hay. In these trials, the feed cost of 100 lbs. gain was 5 per cent less for the cattle fed silage. This might make the difference between profit and a loss on the feeding operation.

In similar tests fattening calves fed corn silage in addition to shelled corn, protein supplement, and legume hay, gained a trifle more rapidly than others fed no silage and sold at a slightly higher price.[13] On the average, corn silage was worth 45 per cent as much as legume hay in these trials.

For carrying calves or older cattle through the winter for later fattening, corn silage has usually been worth fully one-half as much per ton as good legume hay.[14] Cattle wintered on corn silage, hay, and a small allowance of protein supplement will make considerably greater gains than those wintered without silage, unless grain is added to the latter ration. This is because of the grain that well-eared corn silage supplies.

Corn silage is also an excellent roughage for wintering beef breeding cows. In Maryland experiments a ration of corn silage supplemented with soybean oil meal and ground limestone was more satisfactory for beef cows than wintering them on mixed clover-timothy hay.[15] In 4 New York tests corn silage was worth 42 per cent as much per ton as good mixed hay when replacing half the hay in the ration for beef cows.[16]

We can conclude from the various experiments that where corn silage does

not cost more than about one-half as much per ton as alfalfa or other legume hay, the use of silage in addition to hay for beef cattle is thoroughly economical. Where silage costs more than this, in comparison with hay, it may be more profitable to feed hay as the only roughage.

It is shown in Chapter XXVIII that when corn silage is added to a ration of nothing but alfalfa hay for fattening cattle the gains are greatly increased. Each 100 lbs. of silage actually replace about 115 lbs. of hay, without giving credit for the better finish produced by the silage feeding.

Information is given in Chapter XXIX on the best amounts of corn or other silage to feed beef cattle, and on the use of silage as the only roughage.

526. Type of corn silage for beef cattle.—Corn for silage to be used for fattening cattle should be planted at a rate that will permit the development of good ears. This is because grain is needed for the rapid fattening of cattle. Also, in the northern states a variety of corn should be grown which will nearly mature in the average season, instead of raising a rank-growing, late-maturing kind.

Immature, watery corn silage is worth much less per ton than silage made from well-eared corn harvested at the dent stage. A decidedly lower feeding value per acre is therefore secured when the crop is ensiled too early. For example, in an Ohio trial well-matured silage produced 23 per cent more gain per acre on fattening cattle than did silage ensiled at the roasting-ear stage.[17]

527. Corn silage for sheep.—Corn silage is the most widely used succulent feed for the winter feeding of sheep in the United States. This is due both to its cheapness and to its high value for breeding sheep and fattening animals. Not only does it furnish palatable nutrients, but also it aids in preventing constipation. Only silage of good quality should be fed to sheep, for they are much more susceptible than are cattle to injurious effects from eating spoiled or moldy silage. Also, silage which is unduly sour is apt to cause colic and scours.

The value of corn silage for fattening lambs is well shown by the results of 44 experiments in which corn silage has been added to the excellent ration of shelled corn and alfalfa or clover hay.[18] In these experiments a total of 2,434 lambs averaging 60 lbs. in weight at the start were fed for an average of 91 days. In 19 of the trials a small amount of protein supplement was added to the silage ration, as a ration of corn grain, legume hay, and corn silage has slightly less protein than is needed for the most rapid gains.

The silage-fed lambs ate an average of 1.2 lbs. silage, 1.1 lbs. shelled corn, 1.2 lbs. alfalfa or clover hay, and 0.08 lb. supplement a day and gained 0.35 lb. daily. Those fed no silage ate 1.7 lbs. hay and 1.1 lbs. corn a day and gained a trifle less than those fed silage, 0.32 lb. The silage-fed lambs sold for 13 cents more per hundredweight, because of slightly better finish. The chief advantage of feeding silage was in the saving of grain and hay required per 100 lbs. gain. In these trials 1 ton of silage plus 118 lbs. protein supplement saved 1,038 lbs. legume hay and 197 lbs. shelled corn.

Considering not only the feed replaced by silage, but also the slightly more rapid gains and slightly higher selling price, we may conclude from these many trials that good corn silage, thus fed, is usually worth slightly more than one-half as much a ton as legume hay.

In most of the other experiments in which corn silage has been added to other rations the results have been similar.[19] In certain western tests corn silage has had a somewhat lower value when it has been added, usually in very limited amounts, to grain and excellent alfalfa hay.[20]

When fattening lambs are fed either corn or sorghum silage and also legume hay for roughage, it is best to let them have all the silage they will clean up, in addition to what legume hay they will take. This usually produces more rapid and cheaper gains than if the allowance of silage is limited.[21] In very cold weather care must be taken not to feed

more silage than will be eaten before it freezes.

It is interesting to note that lambs given all the silage they desire will still eat nearly as many pounds of hay as of silage, while steers fed the same feeds may eat 5 to 7 times as many pounds of silage as of hay.

When legume hay or good-quality mixed legume-and-grass hay can readily be provided, it is best not to use corn or sorghum silage as the only roughage for fattening lambs or for the breeding flock, but to feed some hay in addition. The legume hay not only helps supply protein, but also it furnishes calcium and supplies vitamin A and other vitamins. The use of corn or sorghum silage as the only roughage for sheep is discussed more fully in Chapter XXXI. If these silages are fed as the only roughages, it is very important to supply a sufficient amount of protein supplement, and also to add ground limestone or some other calcium supplement.

Several experiments have shown that corn silage has a decidedly higher value per ton for fattening lambs, when fed along with good hay, than it does as the only roughage. This is true even when a protein supplement and a calcium supplement are fed. For example, in 3 New York tests, corn silage was worth 56 per cent as much as alfalfa hay when added to a ration of shelled corn, protein supplement and alfalfa hay. However, when silage was fed as the only roughage with corn, protein supplement, and ground limestone, it was worth only 37 per cent as much as the hay.[22]

528. Corn silage for horses and mules.—While silage is fed to horses or mules much less frequently than to cattle or sheep, many farmers have had success in using it. Only silage of good quality, free from decay or mold, should ever be fed to horses, for they are much more apt to be poisoned by spoiled silage than are cattle or even sheep.

Silage should not be the only roughage for horses or mules, but it may replace one-third to one-half the hay usually fed. The animals should be accustomed to it gradually, and certain ones may not eat it readily at first. Because of its bulky nature, animals at hard work cannot consume much silage, but it is well suited to idle horses and mules, brood mares, and growing colts.[23] If the silage contains much corn, the amount of grain that is fed should be reduced accordingly.

529. Corn-fodder or corn-stover silage.—Silage can be made from dry corn or sorghum forage, if the forage is wet thoroughly as it is cut into the silo and if it is tramped down well, so there will not be too much air in the mass after it settles. Otherwise, the forage is apt to mold. When properly ensiled, such forage ferments much as does green fodder in the usual silage process. Though such silage is usually less palatable than silage from green fodder, it is eaten readily by stock and with less waste than in the case of dry fodder or stover.

The water can be sprinkled on the cut material in the silo, but it can be mixed more evenly if a stream is run into the blower, and then more water, if necessary, is sprinkled over the cut forage in the silo, as it is filled. Enough water should be added so that a little can be squeezed out of a handful of the cut material. Generally, about one ton of water should be added to each ton of dry forage.

Since corn-stover silage lacks the grain, it is worth decidedly less per ton than normal corn silage that includes the ears. However, it is more valuable than an equivalent amount of dry corn stover, for it is more palatable and it is eaten with less waste. It is best used for animals that do not need rations rich in digestible nutrients. For example, it is satisfactory as the chief roughage for wintering beef breeding cows (which are not nursing calves) or for wintering stocker cattle that are to be fattened on grass the next summer. If possible, good legume hay should be fed along with stover silage.

On the other hand, it is a mistake to remove the ears from corn forage for silage intended for dairy cows, dairy heifers, fattening beef cattle, beef calves, breeding ewes, or fattening sheep. These

animals all need rations rich in digestible nutrients. If the ears are removed, it will therefore be necessary to replace this grain by feeding larger amounts of concentrates. Even then, the results will usually not be so good as when normal silage, rich in ears, is fed.

530. Corn-stover silage for dairy cattle.—For feeding dairy cows, the labor of removing the ears from corn forage before ensiling it is more than wasted. Experiments many years ago proved clearly that better results are secured from normal well-eared silage than from stover silage, fed with the ground corn grain from the ears that had been removed.[24] Similar results were secured in a recent Michigan trial.[25] In a Wisconsin experiment corn-stover silage, fed with alfalfa hay and a good concentrate mixture, produced 10.6 per cent less milk than did normal corn silage.[26] The stover silage was worth only 61 per cent as much per ton as corn silage containing the ears.

531. Corn-stover silage for beef cattle.—The manner in which corn-stover silage can be used for wintering beef breeding cows is well shown by Illinois tests.[27] Beef cows wintered on 60 lbs. of corn-stover silage per head daily plus 1 lb. of protein supplement, and usually with a little straw in addition, were rather thin in condition but produced thrifty calves. The cost of feed was only one-third as much as with corn silage that contained all the ears. Thus fed, corn-stover silage will be worth from one-half to two-thirds as much per ton as corn silage containing the ears.

Use can also be made of stover silage as part of the roughage for wintering yearling or 2-year-old beef cattle, unless considerable gain in weight is desired during the winter.

Some farmers think that a considerable part of the value of the corn grain is lost when the whole crop is ensiled. They believe that if they husk the corn and later feed it with silage made from the stover, the crop will have a higher value. The contrary has been shown by Michigan and Tennessee experiments in which fattening cattle were fed either stover silage or well-eared corn silage as part of the ration.[28]

532. Dry corn fodder; shock corn.—Though not so palatable and valuable as corn silage, corn grown thickly and cured as dry fodder while the leaves are yet green, makes a coarse forage which may be used as a substitute for hay from the grasses.

As corn fodder is low in protein, it gives the best results when fed with legume hay. Such a combination is satisfactory for dairy cows, beef cattle, and sheep. Corn fodder may also be used as a substitute for hay with idle horses, brood mares, and colts.

Corn fodder and stover should be cured in large, well-made shocks, to reduce the losses from weathering. When corn forage seems dry, it generally still has more water and less dry matter than hay, a fact that should be borne in mind in feeding it. Corn fodder or stover must be well cured before it is stacked, and especially before it is stored in a mow. Otherwise, it will heat and mold badly.

When corn is grown primarily for grain, sometimes the crop is fed as *shock corn,* the stock doing their own husking and eating the corn grain and most of the stover. This method of feeding the crop saves enough labor to make it economical under some conditions, even though the feeding value per acre is commonly much less than when the corn is ensiled.

The relative value of shock corn or corn fodder per acre compared with corn silage will depend to a considerable extent on the usual amount of rainfall in autumn in the particular region. In the corn belt and other humid districts there is a considerably greater loss of nutrients in curing corn fodder in the field than there is in the drier regions.

When shock corn is husked by machinery, the stover is usually shredded or chopped at the same operation. Corn fodder is also often chopped with a silage cutter before feeding. This shredded or chopped material is no more digestible than the uncut forage. However, chopping or shredding usually reduces the wastage. Such forage is also easier to handle, and the waste is in better shape for bedding. Unless shredded or chopped fodder or stover is thoroughly dry, it will heat and mold if a large quantity is stored for any considerable period.

Grinding fodder or stover costs

much more than chopping or shredding it. Grinding is therefore probably not advisable, except that it may pay to grind well-eared fodder finely enough to crack the kernels for stock that would fail to chew the grain thoroughly.

533. Corn fodder for dairy cows.—Though inferior to silage, well-cured corn or sorghum fodder is relished by cows and may be used as a substitute for hay from the grasses. Instead of being fed as the only roughage, it should be used with some legume hay, and it should be chopped or shredded to reduce waste. The portion of corn or sorghum fodder that is eaten is about equal to timothy hay in value. Whole corn fodder was not a very satisfactory feed for dairy cows in Iowa and North Carolina tests.[29]

534. Shock corn; corn fodder for beef cattle.—Both shock corn and corn fodder are often used for beef cattle. Shock corn is frequently fed to fattening cattle, especially during the first part of the fattening period. The cattle soon become used to eating the unhusked ear corn and will also eat most of the leaves and even some of the stalks. In feeding shock corn there is more wastage of grain than in feeding ear corn or shelled corn, even when pigs follow the cattle. It is also rather difficult to adjust the amount of grain as the fattening progresses. The gains are therefore apt to be slower from shock corn, especially during the latter part of the feeding period.

Corn fodder and shock corn are excellent feeds for wintering beef cattle, when a limited amount of legume hay is supplied to balance the ration or when a small amount of protein supplement is fed. Though a considerably greater feeding value per acre is secured when the crop is ensiled, the dry fodder is a very useful feed for those who do not have silos.

In the corn belt and other humid regions, a much greater return per acre is generally secured when corn silage is fed to fattening cattle than when the crop is utilized as shock corn. Thus, in 3 Michigan experiments fattening cattle made fairly good gains on shock corn, fed with a protein supplement and a limited amount of alfalfa hay.[30] However, other cattle fed corn silage in place of the shock corn made somewhat greater gains. Still more important was the fact that the silage produced 55 per cent more gain in liveweight per acre than shock corn when fed uncut, and 15 per cent more than chopped or ground shock corn. Similar results have been secured in most other comparisons of corn silage and shock corn for fattening cattle.[31]

In the drier districts there may not be any great difference in the results from corn silage and from chopped or ground corn fodder as a feed for beef cattle, because the fodder can be cured with but little loss of nutrients. Thus, in Colorado, Nebraska, and North Dakota experiments chopped or ground corn fodder was nearly as satisfactory as corn silage.[32] In feeding value, 100 lbs. of chopped or ground fodder equalled 184 to 228 lbs. of corn silage.

Whether or not it will pay to chop or grind corn fodder or shock corn will depend, first of all, on whether pigs follow the cattle, and also on the quality of the forage and the cost of preparation. Where pigs followed the fattening cattle, it did not pay to chop or grind shock corn in Iowa and Michigan experiments.[33] If shock corn is fed to fattening cattle which are not followed by pigs, it will probably pay to grind the fodder fine enough to crack the corn kernels.

535. Corn fodder for sheep.—Well-cured dry corn fodder is a better roughage for sheep than most timothy hay or other grass hay. However, corn silage is decidedly preferable to the dry fodder and has a considerably higher value per acre. For feeding to sheep, corn fodder had best be chopped to reduce the wastage, instead of being fed uncut. Sometimes it is ground in a roughage mill.

Ground or finely chopped dry corn fodder, including the ears, was compared with corn silage in Colorado and New Mexico trials with fattening lambs, which were fed alfalfa hay and concentrates in addition.[34] The gains were about as rapid on the corn fodder as on corn silage, and

1.0 ton of the chopped or ground dry fodder was equal to 2.5 tons of corn silage in feeding value.

The use of shock corn, grown primarily for the grain, in fattening lambs is discussed in a later chapter. (699)

536. Corn fodder for horses and mules.—Properly-cured corn fodder (especially that thickly grown for forage) is a satisfactory substitute for timothy or other grass hay in feeding idle work stock or animals at moderate work, and for brood mares, stallions, and growing stock. An economical combination for wintering farm horses or mules is half corn fodder or stover and half legume hay. For idle horses, no grain will be needed in addition, except for a few weeks before the spring work begins.

The portion of good corn fodder that is actually eaten is about equal to timothy hay in feeding value. To reduce the waste, it is best to cut or shred the fodder. Even then, there will usually be considerable refuse, but this can be used for bedding.

537. Corn stover.—Though corn stover, the forage which remains after removing the ears from shock corn, is not a high-grade roughage, it has considerable value when properly used. Stover produced in the northern part of the corn belt is superior to that grown in the South. As soon as corn stover is well cured, it should be stacked or placed under cover, rather than being left to waste away in the shock. When corn develops but little grain, because of drouth or hot winds at silking time, the stalks and leaves are higher in digestible nutrients than usual.

IN STOCK FARMING CORN STOVER IS UTILIZED

Corn stover contains at least one-fourth the feeding value of the corn crop. In well-planned stock farming it is well utilized.

In the corn belt the ears are commonly husked or snapped from the standing stalks, and the stover then left uncut in the field. On livestock farms horses, cattle, or sheep are usually turned into these stalk fields to utilize the stover and to get any remaining ears. Considerable feeding value can thus be saved, though the wastage is greater than when the crop is harvested and husked.

Corn stover is too low in nutrients to form any large part of the roughage for high-producing dairy cows. A limited amount of bright, well-cured stover, fed after cutting or shredding, may sometimes be an economical feed for the milking herd. However, better use can us-

ually be made of the stover by feeding it to well-grown heifers, idle horses, or other stock which need less nutrients.

Corn stover can often be fed advantageously as part of the ration for wintering beef cows or even for wintering young beef cattle, but it is too low in nutrients to be of much value for fattening cattle. For example, in an Ohio trial, fattening steers fed corn stover with mixed hay, shelled corn, and protein supplement returned only 81 cents per head

538. Corn as a soiling crop.—Corn ranks high as a soiling crop, because of its palatability, the high yield of nutrients, and the fact that it remains in good condition for feeding during a much longer time than many of the other soiling crops. Green corn fodder is of especial value for dairy cows when pastures are short in late summer or early fall. An acre of ripening corn thus fed in early fall may return twice as much profit as if it were held over until winter.

In Grain Farming Corn Stover Is Largely Wasted

In exclusive grain farming in the corn belt, the ears are picked from the standing stalks, and the stover is then often allowed to waste away in the field.

over cost of feed, while others fed corn silage in place of the stover gave a net return of $6.14.[35]

Corn stover is likewise unsuitable for fattening lambs,[36] but cut or shredded stover may be used as part of the roughage for breeding ewes, if considerable good legume hay is fed in addition.

Corn stover, if well-cured, is satisfactory as part of the roughage for wintering idle horses or mules, especially when fed with legume hay or mixed hay. It does not supply enough net energy to be very useful for horses or mules at work.

For early feeding, sweet corn may often be advantageously used.

If cattle are turned in a field to graze on green corn (forage and ears) before it has matured, they may overeat, causing serious digestive disturbance.

539. Pulling fodder.—In the South the tops of the ripening corn stalks are often cut off just above the ears, leaving the tall butts, each with an unhusked ear at its top. Next the leaves are stripped from the butts, and these together with the severed tops are cured into a nutritious, palatable fodder, which is used for stock feeding. However, "pulling fodder" in this manner is a very unwise practice, for it seriously reduces the yield of grain. During the last stages of its

life the corn plant is busiest in manufacturing and storing nutrients. Removing the top and leaves at once stops all this work of food making.

540. Sweet-corn stover; corn-canning-factory waste.—*Sweet-corn stover,* left after the green ears have been removed for sale on the market or to a canning factory, is of somewhat higher value per ton, on the dry basis, than stover from ripe field corn. It is more leafy, and the leaves and stalks are more nutritious. Silage made from green sweet-corn stover is worth nearly as much per ton as that made from immature field corn which contains but little grain.

The sweet-corn forage should be allowed to mature a few days after the ears are removed, before it is ensiled. It then will be less watery, and the silage will not be too acid. However, it should be ensiled when the stalks and most of the leaves are still green.

The *canning-factory waste* at corn canneries consists of the husks and cobs, with some ears of unsatisfactory quality for canning. This waste is usually ensiled, either in stacks at the factory or in silos on the farms of the growers. Such silage is lower in protein and in total digestible nutrients than silage made from well-matured field corn that has a good proportion of ears. Judging from its composition and digestibility, it is worth about as much per ton as silage from field corn that has but little grain.[37] Silage made from canning-factory waste is sometimes very acid, and may then be rather unpalatable to stock.

541. Corn tassels.—Corn tassels, usually discarded after being clipped from corn plants in producing hybrid corn seed, have been found to be rich in carotene and B-complex vitamins and fairly high in protein.[38] It is estimated that the yield of tassels on the dry basis is about 270 lbs. per acre. If this material could be saved economically, it might well be used for stock feeding.

II. The Sorghums

542. Importance of the sorghums.—In the central and southern parts of the western plains states, the sorghums (*Sorghum vulgare*) are of great importance as feed crops, both for forage and for grain. In fact, success in stock farming throughout this section depends largely on the sorghums. Because they are much more drouth-resistant than corn, they have largely taken its place in those portions of this region that have too little rainfall for corn.

The importance of the sorghums in the United States is shown by the fact that as much as 17,000,000 acres are grown annually. Of the total acreage, more than half is usually raised for grain, only about a million acres for silage and the rest for dry fodder. Of our acreage, all but a small percentage is grown in ten states—Texas, Kansas, Oklahoma, Colorado, Nebraska, New Mexico, Missouri, South Dakota, Arizona, and California.

Sorghums are also important as forage crops in certain sections of the South where they yield much more forage per acre than corn, since they produce a fair crop on soil too poor or thin for corn.

Where there is sufficient rainfall, corn usually excels the sorghums, both for grain production and for forage. For this reason the acreage of the sorghums is small in the corn belt and eastward. However, corn requires a plentiful supply of moisture throughout the growing season, and the yield is always unsatisfactory if growth is seriously checked by drouth.

The sorghums will cease growing and the edges of the leaves roll together during periods of drouth and extreme heat. Yet, when rain comes, the plants quickly resume growth, unless they have been killed by the drouth. In the drier parts of the sorghum belt, milo and other dwarf varieties are grown which not only are more drouth resistant but also evade drouth, because they are early maturing. Like corn, the sorghums require warm weather throughout the growing season. In fact, they are even more particular than corn in this respect.

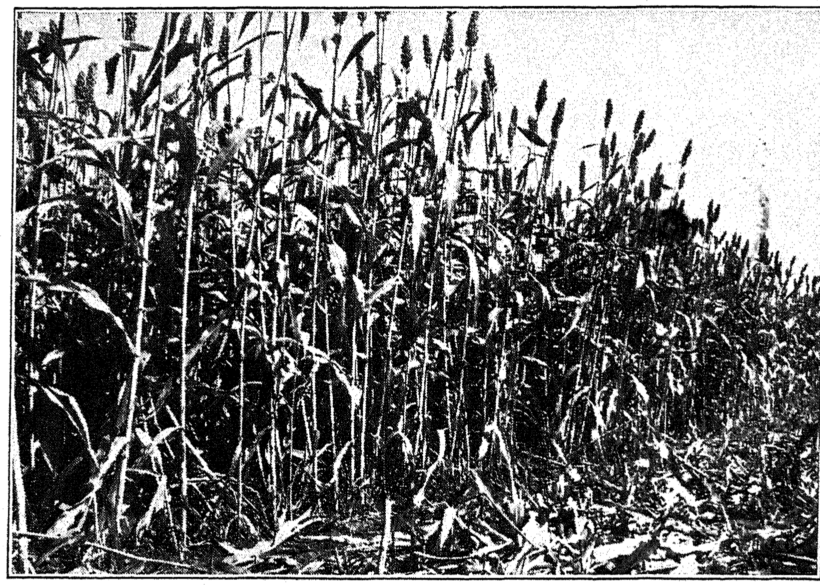
543. Types of sorghums.—The sorghums are of two general types—the *sweet sorghums,* or *sorghos,* which have stems filled with sweet juice, and the *grain sorghums,* which have juice that is not sweet or only slightly sweet and which usually have more pithy stems. *Broom corn* is another type of sorghum that is raised for the heads, or brushes, which are used in the manufacture of brooms. When the term "sorghum" is

used without the words "sweet" or "grain," in referring to silage, fodder, or stover, the product from sweet sorghum is usually meant.

The sweet sorghums, or sorgos, often called "cane" by farmers, are forage rather than grain producers. They are usually 5 to 7 feet tall or more. In most sections of the sorghum belt the varieties of sweet sorghum that are adapted to the particular locality give larger yields of forage per acre than the best grain sorghums.

rather dry, pithy stalks. They are not commonly grown for forage.

The taller grain sorghums, such as kafir and hegari, are used for both grain and forage. Atlas, Axtell, Ellis, and Norkan, which are crosses between grain sorghum and sweet sorghum, are also used for both forage and grain. Darso, shrock, and sagrain are other sorghums produced by such crosses, which are grown in some areas. These dual-purpose sorghums are leafy and have juicy, sweet stalks.



ATLAS SORGHUM GROWN FOR SILAGE

Atlas sorghum is one of the most popular varieties of sorghum for forage in the eastern part of the sorghum belt.

The two types of sorghum cross freely. Through crossing, certain hybrid varieties have been developed that combine some of the characteristics of both the grain sorghums and the sweet sorghums.

The sorghums now grown for grain in the sorghum belt are now mostly dwarf varieties, which can readily be combined. These varieties, mostly developed by crossing milo with kafir or other sorghums, grow only 2 to 4 feet tall, have erect heads, and usually have

544. Composition and nutritive value of sorghum forage.—Sorghum forage resembles corn forage in composition, but unless it has a high proportion of grain, it will have decidedly less total digestible nutrients than well-eared corn forage.

Another reason for a somewhat lower content of total digestible nutrients in sorghum forage for cattle is that they do not utilize the grain in sorghum fodder or silage quite so well as they do the grain in corn fodder or silage. Because

the grain is much smaller in size, somewhat more escapes chewing and passes through the digestive tract with little change. There is not this difference in the case of sheep, since they chew their feed more thoroughly.

Since sorghum grain is lacking in carotene, sorghum forage which includes the grain will have considerably less vitamin A value than well-eared corn forage of yellow corn varieties. Indeed, in Texas experiments with beef calves fattened in dry lot over long periods, sorghum silage, fed as the only roughage, did not supply enough vitamin A value to meet their needs fully.[39] They often began to show slight symptoms of vitamin A deficiency before they were ready for market. The lack of vitamin A can be readily corrected by feeding a pound or so of good-quality alfafa hay per head daily.

When sorghum forage, either silage or dry fodder, is fed as the only roughage for no longer than the usual feeding period, the difference in vitamin A value is the only great difference in nutritive value between sorghum forage and corn forage. However, in long-time Kansas experiments in which sorghum forage and sorghum grain were fed continuously to dairy cattle, without any pasture, other deficiencies showed up, even when protein and mineral supplements were provided.[40] Cows so fed eventually became unthrifty and produced much less milk than when legume hay was fed in addition. Similar results were secured in New Mexico and Nebraska experiments.[41]

It has been stated in Chapter VIII that there seems to be more trouble from urinary calculi in cattle and sheep when sweet sorghum forage is fed than with other roughages, possibly due to a high content of silicates. (250)

545. Prussic acid in sorghum forage.—Green sorghum plants of most varieties may contain sufficient prussic acid, or hydrocyanic acid, to cause the death of cattle or sheep, as is pointed out later. (**670**) The prussic acid content is apt to be high enough to be dangerous in young plants and when the growth is checked by drouth or other injury.

If sorghum is harvested when approaching maturity, it is not usually dangerous. Also, the prussic acid is destroyed to a considerable extent when the forage is thoroughly dried as dry fodder or hay, and it is still more completely destroyed when the crop is ensiled. Therefore well-dried sorghum is generally safe, and practically no cases of prussic acid poisoning have been reported from sorghum silage. Even green sorghum rarely causes prussic acid poisoning in the humid sections of the southern states. Low-prussic-acid varieties of sorghums have recently been developed which have not been known to cause poisoning of stock, even when pastured.[42]

Sorghum grain never causes prussic acid poisoning.

546. Sorghum fodder or hay.—Dry sorghum fodder, often called "bundle feed," is of great importance for stock feeding in the sorghum-growing districts. Indeed, the acreage of sorghums grown for dry fodder in this country is nearly as large as the acreage raised for grain, and it is several times as large as the acreage grown for silage.

For dry forage, varieties of sorghum with sweet, juicy stalks are generally grown, as the forage is more palatable. The crop should be cut when the seed is in the dough stage. Sorghum fodder or hay must be thoroughly cured in shocks, windrows, or cocks before it is stacked or stored in the barn, or it will sour or mold. In humid regions it had best be left in the field in shocks or cocks, and drawn to the feed lot or barn from week to week during the barn-feeding season, as it is difficult to get the stalks dry enough for storage in bulk.

Sweet-sorghum hay or fodder, often called "cane hay," is lower in fiber and slightly higher in total digestible nutrients than average timothy or prairie hay, but there is more waste in feeding it unless it is cut or shredded. Because of its sweetness, it is somewhat more palatable than corn fodder. Fodder from the grain sorghums, including the grain, may have as high a value per ton as that

from sweet sorghum. Though the stalks are less nutritious, the proportion of grain is usually larger.

Sorghum fodder harvested when the leaves were no longer very green was deficient in carotene in New Mexico trials, while early-cut, well-cured fodder had plenty for dairy cows.[43]

Well-cured sorghum fodder or hay is a satisfactory roughage for dairy cattle, beef cattle, sheep, and horses, when fed in a well-balanced ration. The value per ton will vary widely, depending on the leafiness, on the proportion of grain, and on how well it is cured. Except for work horses, it usually gives the best results when fed with some legume hay. If no legume hay is available, ground limestone or some other calcium supplement should be supplied. Except in very dry regions where the sorghum can be cured into excellent dry fodder with only a small loss of nutrients, a much higher feeding value per acre is secured from sorghum silage than from sorghum fodder.

Whether or not it will pay to chop or grind sorghum fodder will depend on the proportion that would be wasted if it is fed whole. For example, in a Texas trial chopping rather poor-quality grain sorghum fodder increased the value for fattening cattle enough to justify the expense.[44] On the other hand, in Kansas tests chopping good-quality kafir fodder did not increase its value for beef cattle being carried through the winter.[45] Grinding the fodder in a mill that cracked most of the grain did, however, increase its value considerably.

547. Sorghum fodder for dairy cattle.—In the plains states and in the South, sorghum fodder is a common feed for dairy cattle, resembling corn fodder in feeding value. It had best be fed with some legume forage, and even then it is usually of lower value than sorghum or corn silage, on the dry matter basis. Chopping or shredding sorghum fodder for dairy cattle is advisable to lessen the wastage.

548. Sorghum fodder or hay for beef cattle.—Cured forage from the sweet sorghums and the grain sorghums can be used for beef cattle in the same manner as corn fodder.[46] Sorghum hay, or "cane hay," made from thickly-planted sweet sorghum, is about equal to good prairie or timothy hay, for there is but little waste in feeding it.

Sorghum forage gives especially good results when fed with a limited amount of legume hay. However, chopped or ground sorghum fodder of good quality has been satisfactory as the only roughage for fattening cattle when fed with a sufficient amount of protein supplement to balance the ration and also with about 0.1 lb. per head daily of ground limestone or other calcium supplement.

Although sorghum fodder is a very satisfactory feed for beef cattle, a much greater feeding value per acre is secured when the crop is ensiled, except in districts where the autumns are very dry.

549. Sorghum fodder or hay for sheep.—For fattening lambs, sorghum fodder or hay usually gives decidedly better results when some legume hay is fed in addition than when it is the only roughage.[47] In some tests the results have been satisfactory, however, with chopped or ground sorghum fodder as the only roughage, when plenty of protein supplement and also a calcium supplement were supplied.[48]

Sorghum fodder is a good feed for wintering ewes if it is properly supplemented. Including some legume hay or other legume forage in the ration is desirable as insurance against nutritive deficiencies. However, in South Dakota trials sorghum fodder, with a protein supplement and minerals, was satisfactory as the only roughage for ewes.[49]

550. Sorghum fodder or hay for horses and mules.—Well-cured sorghum fodder or hay is excellent for horses and mules, and is satisfactory as the only roughage for mature horses. In a Nebraska test sorghum fodder was superior to prairie hay as part of the ration for colts.[50] Moldy, decayed sorghum forage is dangerous to horses.

551. Sorghum stover.—Sorghum stover (sorghum fodder from which the

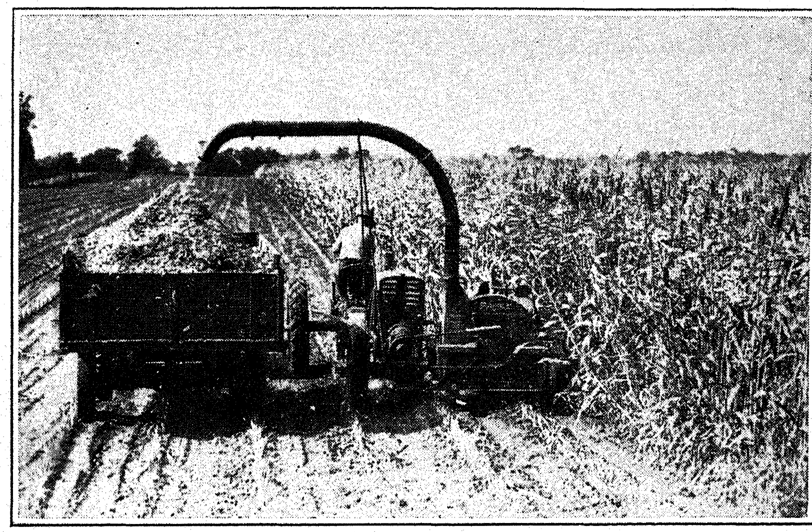
heads have been removed) is similar to corn stover in composition and general value. Stover from kafir, hegari, darso, or the sweet sorghums is the best, as it is leafier and the stalks are more nutritious than in the case of stover from milo, kaoliang, or durra.

Like corn stover, sorghum stover is best used for stock which is not being fed for high production. Thus, it is more valuable for wintering beef breeding cows, stocker cattle, or work stock than it is for milk cows, for fattening cattle or lambs, or for horses or mules at hard work. Since sorghum stover is very low in protein and may be deficient in calcium, supplements should be fed to meet these lacks when the stover is not fed with legume roughage.

For wintering beef calves sorghum stover was about equal to prairie hay in a Nebraska test, but inferior to sorghum silage.[51] Ground hegari stover, undoubtedly of good quality, was satisfactory as the only roughage for fattening calves in Texas trials.[52]

In Kansas trials ground sorghum stover was a satisfactory and economical roughage for fattening lambs, especially when fed with some alfalfa hay.[53] In a New Mexico test chopped sorghum stover was a better roughage than cottonseed hulls or corn stover for fattening lambs.[54]

552. Sorghum silage; sorghum-stover silage.—The sorghums make excellent silage if ensiled when the seeds are hard and ripe. Such silage contains no more acid than does corn silage and is well liked by stock. If the plants are immature, the silage will be too sour. Also, the crop will have much less feeding value per acre if ensiled before the storage of nutrients in the seeds is practically completed. For example, in Arkansas experiments with beef calves, Atlas sorghum ensiled when well matured or at least in the early dough stage produced more than twice as much gain per acre as did silage made at the early boot stage.[55]



HARVESTING SORGHUM FOR SILAGE WITH A FIELD CHOPPER

A sorghum crop has a much higher feeding value when it is ensiled, than when it is fed as dry fodder or hay.

A good way to determine whether sweet sorghum or kafir is mature enough for silage is to twist the stalk with the hands. If just a little juice is visible on the twisted cane, the proper stage has

been reached. If the crop does not mature enough before frost, fairly good silage can be made by allowing it to dry out somewhat before ensiling it. Also, immature sorghum which has been withered by drouth can be used successfully for silage. Water should be added, if the forage is too dry to pack well in the silo.

A sorghum crop has a much higher feeding value per acre when ensiled than when fed as dry fodder or hay. In spite of this fact, about 5 times as many acres are grown for dry fodder as for silage. Some farmers who use sorghum fodder have too few cattle to keep silage from spoiling. Others find the dry fodder more convenient to use as a supplement to winter range or pasture.

Sorghum silage is excellent for dairy cattle, beef cattle, and sheep. If sorghum silage is fed to horses, the same precautions should be taken as with corn silage. (**528**) The value per ton of sorghum silage is usually somewhat less than that of well-eared corn silage, because sorghum silage is not so rich in grain. Also, cattle do not chew the seed in sorghum silage as thoroughly as they do corn grain. A considerable percentage, therefore, passes through undigested. However, in the sorghum belt the yield of the sorghums is so much greater than that of corn that they far surpass corn for silage. This is also the case in certain sections of the South. There is generally no danger from prussic acid poisoning in feeding sorghum silage to stock.

Trench or pit silos provide a cheap means of storing silage in the sorghum belt and are therefore widely used. Since sorghum silage keeps well from one year to another, or even longer, many farmers in the dry-farming districts store silage in a good year to carry over to a time of drouth.

Silage is sometimes made from sorghum stover, after the heads are harvested. Since the silage can be made from the leaves and stalks while still green, sorghum-stover silage is more palatable to stock than silage made from dry corn stover with the addition of water. Also, for cattle there is not quite so much difference between the value of sorghum silage containing the heads and of sorghum-stover silage, as there is between normal corn silage and corn-stover silage. This is because more of the seed escapes chewing in the case of sorghum silage. Sorghum-stover silage was worth 87 per cent as much per ton as sorghum silage containing the heads in Oklahoma tests with dairy cows, and about 74 per cent as much in Kansas tests with beef calves being wintered.[56]

Because of its lower content of nutrients, stover silage had generally best be used for wintering beef cows, stocker cattle, or well-grown dairy heifers, instead of for cows in milk or for fattening cattle.

553. Sorghum silage for dairy cattle.—Sorghum silage ranks next to corn silage in value for dairy cattle. It is worth somewhat less per ton than such corn silage as is normally produced in the corn belt. However, where the climatic conditions are more favorable to the sorghums than to corn, as in the southern plains states, sorghum silage may be nearly as valuable per ton as the corn silage produced there.[57]

Sorghum silage has this high value for dairy cows in spite of the fact that a much larger proportion of the seed passes through the animal unmasticated and undigested than in the case of corn silage. It has been found that one-fourth or more of the seeds in sorghum silage are voided in the manure with little change.[58] This is a much larger loss than occurs in the case of corn silage.

There is apparently not much difference in the value per ton of silage from the grain sorghums and from the sweet sorghums for dairy cows, judging from the results of Kansas and Oklahoma tests.[59]

554. Sorghum silage for beef cattle.—Sorghum silage is of great importance for beef production in those sections where the climate is such that the sorghums yield much more forage per acre than corn. Except where weather conditions in the fall are ideal for curing sorghum as dry fodder, the feeding value

of sorghum silage per acre will be considerably greater than that of sorghum fodder.

Sweet sorghum silage is generally worth somewhat less per ton for beef cattle than silage from the grain sorghums or such hybrids as Atlas sorghum, as it contains much less grain. However, in many districts the yield of the sweet sorghums is enough greater to more than make up this difference.

When sorghum silage is added to a ration for beef cattle in which the only roughage is alfalfa or other hay, sorghum silage will usually be worth 30 to 40 per cent as much per ton as alfalfa hay, or about one-half as much per ton as prairie hay or oat hay.[60] If fed as the only roughage, its value will tend to be slightly lower than this.

For beef cattle that are being wintered on moderate rations, the value of sorghum silage per ton approaches that of such corn silage as is generally produced in the plains states. In 7 Kansas and Nebraska tests in which calves were wintered on either sorghum silage or corn silage with 1 lb. per head daily of cottonseed meal, the gain has been nearly as great on the sorghum silage.[61] Each 100 lbs. of sorghum silage were equal in average feeding value to 87 lbs. of corn silage.

For fattening cattle the value of Atlas sorghum silage or sweet-sorghum silage has been considerably lower than that of such well-eared corn silage as is commonly produced in the corn belt. For example, in Indiana and Illinois trials fattening cattle made nearly as rapid gains on Atlas silage as the main roughage as others did on corn silage.[62] However, in the Illinois trials the Atlas silage was worth only 60 per cent as much as corn silage for fattening cattle and 70 per cent as much for wintering beef calves.

In 15 other tests cattle gained 1.78 lbs. per head daily, on the average, on sweet-sorghum silage and 1.99 lbs. on corn silage.[63] On account of poorer finish, the cattle fed sorghum silage generally sold for a slightly lower price. Due to this and because somewhat more feed was required per 100 lbs. gain on sorghum silage, the actual feeding value of sorghum silage was only 58 per cent as great per ton as that of corn silage. These results show that sweet sorghum should not be grown in place of corn silage for fattening cattle, unless the average yield is enough larger to make up the difference in value per ton.

555. Sorghum silage for sheep.—Sorghum silage is a good substitute for corn silage in feeding sheep.[64] Except in the drier regions where sorghum fodder can be cured with little loss of nutrients, a higher value per acre is secured when the crop is ensiled than when it is fed as dry fodder.

Like corn silage, sorghum silage usually gives decidedly better results for fattening lambs or breeding ewes when fed in combination with some legume or mixed hay than when used as the only roughage. This is true even when protein and calcium supplements are properly provided.

In Kansas and Texas tests it required only 2.3 tons of sweet-sorghum silage to equal 1 ton of ground sweet-sorghum fodder for fattening lambs.[65]

556. The sorghums for pasture and as soiling crops.—The common varieties of sorghum are not generally used for cattle or sheep pasture, because of the danger of prussic acid poisoning. **(670)** Sudan grass is generally used instead, for it is not only much safer, but it is also a better pasture crop. Horses and swine can be grazed safely on sorghum. However, sorghum has too much fiber to rank high as a pasture for pigs. For older hogs fed considerable grain, it gives somewhat better results.[66]

Except for the danger of prussic acid poisoning, the sorghums are satisfactory as soiling crops. If the crop is allowed to reach the seed stage before it is fed, the danger is slight.

557. Dehydrated sorghum forage.—Sometimes sorghum fodder is dehydrated, in the same manner as alfalfa. This efficiently preserves the nutrients, but is expensive. In a Kansas test with dairy cows dehydrated Atlas sorghum had the same value as Atlas silage per pound of dry matter.[67] In another

Kansas trial with fattening lambs a pelleted ration made up of dehydrated sorghum, sorghum grain, and cottonseed meal produced slightly more rapid but decidedly more expensive gains than a ration of ground sorghum fodder, whole sorghum grain, and cottonseed meal.[68]

558. Perennial hybrid sorghums.—In Argentina a natural hybrid between sweet sorghum and Johnson grass (*Sorghum almum*) is a good perennial pasture crop in the drier areas. This does not spread by rootstalks and become a pest, as does Johnson grass. It has given promising results in Georgia.[69] Perennial sorghum hybrids are also being studied at the Mississippi and Hawaii Stations.[70]

559. Broom-corn-stover silage.—Many farmers believe that the broom-corn stover which is left after the brush is harvested is valueless or actually injurious for feeding. However, in Illinois tests broom-corn stover made fairly satisfactory silage when ensiled as soon as the brush was harvested and when 100 lbs. of molasses were added per ton.[71] Silage made without molasses did not keep well. The silage was somewhat less palatable to dairy cows than normal silage, but they ate it readily after becoming used to it and produced only slightly less milk than when fed corn silage.

QUESTIONS

1. What are the merits of corn as a forage crop?
2. Define corn fodder; shock corn; corn stover.
3. What factors should determine how closely corn should be planted for forage?
4. Explain why corn should not generally be cut for silage until the glazing stage.
5. State the main facts concerning the composition of corn forage, considering content of protein, total digestible nutrients, calcium, phosphorus, vitamin A value, and vitamin D.
6. Approximately what part of the digestible protein and net energy of a corn crop grown for grain is in the stover?
7. Why does corn excel as a silage crop?
8. Under what conditions might you advise a dairyman in the northern states to grow a late-maturing variety of corn for silage?
9. Why does an acre of corn silage generally have a decidedly higher value than an acre of dry corn fodder?
10. Discuss the value of corn silage for dairy cattle, stating the approximate value per ton of corn silage and good hay.
11. Similarly, discuss the value of corn silage for: (a) Beef cattle; (b) sheep; (c) horses and mules.
12. What type of corn silage is best for fattening cattle?
13. Discuss the making and use of corn-fodder silage and corn-stover silage.
14. Discuss the use of corn fodder for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules.
15. For what classes of stock and in what manner can corn stover be used best?
16. How does corn rank as a soiling crop?
17. In what sections of the country are the sorghums superior to corn for forage?
18. What are the differences between the sweet sorghums and the grain sorghums?
19. If sorghums are important in your region, describe the characteristics of the 3 chief varieties raised there.
20. Discuss the composition and nutritive value of sorghum forage.
21. Discuss the use of sorghum fodder for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules.
22. For what classes of stock is sorghum stover most suitable?
23. Discuss the value of sorghum silage for: (a) Dairy cattle; (b) beef cattle; (c) sheep.
24. Why is not sorghum used widely as a pasture for cattle or sheep?

REFERENCES

1. Jones, Ind. Bul. 175; see also: Miller, Kan. Tech. Bul. 54; Rather and Marston, Mich. Quar. Bul., 22, 1940, No. 4; Kiesselbach, Nebr. Res. Bul. 166; Ladd, N.Y. (Geneva) Rpt. 1899; Hopper, N.D. Bul. 192.
2. Bechtel and Hoppert, Mich. Quar. Bul. 18, 1936, No. 3; Bechtel, Huffman, Duncan, and Hoppert, Mich., Jour. Dairy Sci., 19, 1936, pp. 359–372.
3. Nevens and Dungan, Ill. Bul. 494; Armsby, Penn. Rpt. 1887; Livesay, VanLandingham, and Schneider, West Va. Bul. 298.
4. Niedermeier, Bohstedt, and Peterson, Wis. Bul. 460; Wis. Cir. 337.
5. Bohstedt, King, Rupel, Zehner, and Neal, Wis. Bul. 451; Nevens and Dungan, Ill. Bul. 494.
6. White, Johnson, and Connelly, Conn. (Storrs) Bull. 167; Conn. (New Haven) Bul. 357; Nevens, Ill. Bul. 391; Ind. Rpt. 1926; Sax and Burgess, Maine Bul. 330; Rather and Marston, Mich. Quar. Bul., 22, 1940, No. 4; Hays, Minn. Bul. 40; Higgins, N.H. Bul. 304; Sprague, Farris, Colby, and Curtis, N.J. Bul. 537; Wiggans, N.Y. (Cornell) Memoir 152; Christensen, N.D. Bul. 286; Hayden and Perkins, Ohio Bul. 369; Gerlaugh and Rogers, Ohio Bimo. Bul. 198; Noll and Irvin, Penn. Bul. 289; Odland and Knoblaugh,

R.I. Bul. 257; Livesay, Buchanan, and Van-Landingham, West Va. Bul. 290; Henry, Wis. Rpt. 1888.
7. Nevens, Harshbarger, Touchberry, and Dungan, Ill. Bul. 576; Huffman and Duncan, Mich. Quar. Bul., 37, 1954, No. 1.
8. Dunn, Ely, Huffman, and Duncan, Mich., Jour. Dairy Sci., 38, 1955, pp. 58–64; Brown, Mich. Rpt. 1927; Hills, Vt. Rpt. 1892; Woll. Wis. Rpts. 1891, 1892.
9. McCandlish and Weaver, Iowa Bul. 212.
10. White, Conn. (Storrs) Bul. 192; White and Johnson, Conn. (Storrs) Bul. 198; Fairchild and Wilbur, Ind. Bul. 297; Jordan, Me. Rpt. 1889; Huffman and Duncan, Mich., Jour. Dairy Sci., 37, 1954, pp. 957–966; Clark, Mont. Bul. 94; Keyes and Smith, Mont., Jour. Dairy Sci., 38, 1955, p. 614; Snyder, Nebr. Rpts. 1923, 1924; Foster and Weeks, N. Mex. Bul. 122; Carroll, Utah Bul. 190; Hills, Vt. Rpt. 1901; Converse, U.S.D.A., Jour. Dairy Sci., 11, 1928, pp. 179–188.
11. McDowell, U.S.D.A., information to the author.
12. Skinner, Cochel, and King, Ind. Buls. 129, 136, 153, 167, 178, 191, 206; Evvard and Pew, Iowa Bul. 182 and Breeder's Gaz., 61, 1912, p. 1040; Evvard, Culbertson, et al., Iowa, mimeo. reports and Amer. Soc. Anim. Prod., Proc. 1923; Peters and Carnes, Minn. Bul. 200; Allison, Mo. Bul. 112; Gramlich, Nebr., mimeo. rpts.; Blizzard, Okla. Bul. 147; see also: Guilbert, Cal. Bul. 481; Maynard and Osland, Colo. Press Buls. 74, 77; Osland, Colo. Bul. 380; Hickman, Rinehart, and Johnson, Id. Bul. 209; Gramlich, Nebr., mimeo. rpts.; Klosterman, Kunkel, Bentley, and Burroughs, Ohio Res. Bul. 732; Ore. Bul. 359; Bentley, Penn. Bul. 446; Hackedorn, Sotola, and Bean, Wash. Bul. 186.
13. Ill. Sta., mimeo. rpt.; King, Ind., mimeo. rpt.; Leinbach, Md. Bul. A-20.
14. Branaman and Harrison, Mich. Quar. Buls., 28, 1945, Nos. 1 and 4; 29, 1947, No. 4; Gramlich, Nebr., mimeo rpts.; Ore. Bul. 359; McCone, S.D. Bul. 407; Hackedorn, Sotola, and Bean, Wash. Bul. 186.
15. Md. Rpts. 1944, 1947; Md. Bul. A-50.
16. Miller and Morrison, N.Y., Jour. Anim. Sci., 9, 1950, pp. 243–247.
17. Gerlaugh and Rogers, Ohio Bimo. Bul. 223.
18. Maynard, Morton, and Osland, Colo. Bul. 379; Coffey, Ill., information to the author; Skinner and King, Ind. Buls. 162, 168, 179, 184, 192, 202; Evvard et al., Iowa Bul. 299; Paterson and Winchester, Kan. Cir. 88; Brown, Mich. Spec. Bul. 233; Gramlich, Nebr. Bul. 173 and information to the author; Savin, Nebr. Bul. 197; Fox, Nebr. Bul. 211; Holden, Nebr. Bul. 268; Willman and Morrison, N.Y. (Cornell) Bul. 691; Maynard, Esplin, and Boswell, Utah Bul. 238; Hackedorn, Bean, and Sotola, Wash. Bul. 185.
19. Culbertson, Iowa Rpt. 1945, Part 1; Jordan and Peters, Minn., mimeo. rpt.; Holden, Nebr. Bul. 268; Neale and Koger, N. Mex. Buls. 335, 369; Bell, Ohio, mimeo. rpt.; Jordan, S.D. Cir. 106; see, however, Keith and Henning, Penn. Bul. 288.
20. Hickman, Rinehart, and Johnson, Id. Bul. 194; Johnson, Id. Bul. 236; Vinke and Hansen, Mont., mimeo rpt.; Fleming and Young, Nev. Rpt. 1940; Aune, S.D. Rpt. 1938.
21. Coffey, Ill., information to the author; Skinner and King, Ind. Buls. 162, 168, 179; Hackedorn, Bean, and Sotola, Wash. Bul. 185.
22. Willman and Morrison, N.Y. (Cornell) Bul. 691; see also: Kammlade, Ill., mimeo rpt.; Harper, Ind. Bul. 470; Ohio Bul. 592.
23. Ariz. Rpt. 1918; Trowbridge and Chittenden, Mo. Bul. 210; Fuller, Roche, and Bohstedt, Wis. Bul. 420.
24. Hills, Vt. Rpt. 1892; Woll, Wis. Rpts. 1891, 1892.
25. Dunn, Ely, Huffman, and Duncan, Mich., Jour. Dairy Sci., 38, 1955, pp. 58–64.
26. Morrison, Humphrey, and Hulce, Wis. Bul. 323.
27. Rusk, Ill. Rpts. 1926, 1927; Hamilton and Rusk, Ill. Bul. 291; Bohstedt, Ohio, information to the author.
28. Brown, Mich. Rpt. 1927; Jacob and Duncan, Tenn. Bul. 149.
29. Iowa Rpt. 1929; Grinnells, N.C. Rpt. 1929.
30. Branaman, Brown, and Hudson, Mich. Spec. Bul. 293.
31. Mumford, Ill. Bul. 73; Allison, Mo. Bul. 112; Jacob, Tenn. Rpts. 1938, 1940. However, see also: Skinner and King, Ind. Bul. 396; Culbertson et al., Iowa Rpts. 1937, Part 2; 1938, Part 2.
32. Morton, Colo. Rpt. 1927; Thalman, Nebr. Bul. 343; Christensen, N.D. Bul. 286.
33. Culbertson, Shearer, Helser, Beard, and Thomas, Iowa Rpts. 1938, Part 2; 1939, Part 2; Branaman, Brown, and Hudson, Mich. Spec. Bul. 293.
34. Maynard, Morton, and Osland, Colo. Bul. 379; Neale, New Mex. Bul. 222.
35. Bohstedt, Ohio Bimo. Buls. 83–84.
36. Skinner and King, Ind. Bul. 273; Brown, Mich. Spec. Bul. 233; see also: Cox, New Mex. Bul. 179.
37. Nevens, Ill. Bul. 391; McCandlish, Iowa, Jour. Dairy Sci., 3, 1920, pp. 370–374; Beattie, U.S.D.A. Farmers' Bul. 1634.
38. VanLanen, Tanner, and Pfeiffer, U.S.D.A., Science News Letter, July 27, 1946.
39. Jones et al., Tex. Bul. 630.
40. Atkeson, Bechtel, Shaw, and Hughes, Kan. Rpt. 1938–40; Bechtel, Atkeson, and Hughes, Kan. Rpt. 1940–42.
41. New Mex. Rpts. 1936, 1940, 1943; Davis, Hathaway, and Trimberger, Nebr. Rpt. 1942.
42. Franzke, S.D. Cir. 57.
43. Cunningham and Addington, New Mex. Bul. 257; Skaggs, N. Mex. Bul. 351.
44. Jones, Dickson, Black, and Jones, Tex. Rpt. 1932.
45. McCampbell et al., Kan., Annual Cattlemen's Round-up, 1934.
46. Williams and Smith, Ariz. Bul. 107; Hilston and Gifford, Ark Bul. 463; Connell and Tom, Colo. Farm Bul., 7, 1945, Nos. 1, 3; McCampbell et al., Kan., Annual Cattlemen's Round-up, 1934; Miss. Rpt. 1947; Thalman, Nebr. Bul. 343; Baker, Nebr. Bul. 350; Lantow, Black, and Burnham, New Mex. Bul. 156; Knox, New Mex. Bul. 343; Darlow, Campbell, Cross, Heller, and Briggs, Okla. Bul. 296; Jones, Black, and Keating, Tex. Bul. 363; Jones, Jones, and Black, Tex. Bul. 604; Stangel and Jones, Tex. Rpt. 1943; Texas Bul. 724.
47. Cox and Sloan, Kan. Rpt. 1938–40; Bell and Erhart, Kan. Cir. 308; Neale, New Mex. Bul. 250; Darlow, Okla. Bul. 213; Jones and Bayles, Tex. Rpt. 1940.
48. Morton, Maynard, and Brandon, Colo. Bul. 395; Cox and Connell, Kan. Bul. 264; Neale, New Mex. Bul. 272; Jones, Stangel, and Dickson, Tex. Rpts. 1929, 1930, 1931, 1932.
49. Johnson and Staples, S.D. Bul. 395.
50. Nebr. Rpt. 1939.
51. Baker, Nebr. Bul. 350.

52. Jones, Hall, and Jones, Tex. Rpt. 1933.
53. Bell and Erhart, Kan. Cirs. 283, 293, 297.
54. Cox, New Mex. Bul. 179.
55. Hilston and Gifford, Ark. Bul. 463.
56. Kuhlman, McGilliard, and Weaver, Okla. Rpt. 1932–34; Weber, Kans. Rpts. 1936–38, 1938–40.
57. Cunningham and Reed, Ariz. Bul. 122; Woll and Voorhies, Cal. Bul. 282; Reed and Fitch, Kan. Cir. 28; see also: Ind. Rpt. 1941; Grinnells, N.C. Rpts. 1929, 1930; LaMaster and Morrow, S.C. Bul. 254.
58. Cave and Fitch, Kan. Cir. 110; Fitch and Wolberg, Kan., Jour. Dairy Sci., 17, 1934, pp. 343–350; Moore, Miss. Rpt. 1927; Becker and Gallup, Okla. Bul. 164; LaMaster and Morrow, S.C. Bul. 254.
59. Reed and Fitch, Kan. Cir. 28; Fitch, Kan. Rpts. 1926–28, 1928–30; Becker and Gallup, Okla. Bul. 177.
60. Stanley and Walker, Ariz. Bul. 170; Ariz. Rpt. 1948; McCampbell and Winchester, Kan. Cir. 77; McCampbell, Anderson, and Marston, Kan. Cir. 128; Baker, Nebr. Bul. 350; Blizzard, Okla. Bul. 237; Ross, Stephens, MacVicar, and Campbell, Okla. Misc. Pubs. MP-13, 14.
61. Cochel, Kan., Amer. Soc. Anim. Prod., Proc. 1915–16; McCampbell et al., Kan., Annual Cattlemen's Round-up, 1931; Thalman, Gramlich, and Lewis, Nebr., mimeo. rpts.; Thalman, Nebr. Bul. 343.
62. King, Ind. Bul. 600; Snapp, Ill., mimeo. rpt.; Ill. Rpt. 1938–47.
63. Good, Horlacher, and Grimes, Ky. Bul. 233; Goodell, Miss. Bul. 222; Buchanan, Miss. Bul. 278; Blizzard, Okla. Bul. 139; Duncan, Tenn. Rpt. 1944; Quesenberry, U.S.D.A. Bul. 1318; see also: Trowbridge and Dyer, Mo. Bul. 490; Gerlaugh and Rogers, Ohio Bul. 659.
64. Stanley and Scott, Ariz. Bul. 109; Miller, Cal. Rpt. 1919; Cox and Connell, Kan. Bul. 264; Stangel, Jones, and Mackey, Tex. Rpt. 1933.
65. Cox and Connell, Kan. Bul. 264 and mimeo. rpt.; Stangel and Jones, Tex., mimeo. rpt.
66. Gray, Duggar, and Ridgway, Ala. Bul. 143; Martin, Ark. Bul. 321; Scott, Fla. Bul. 113; Hansen, Seamans, and Mosley, Mont. Rpt. 1927.
67. Fountaine, Farrish, and Bartley, Kan. Rpt. 1948–50.
68. Bell and Erhart, Kan. Cir. 308.
69. Morrison, Ga., Crops and Soils, Jan. 1953.
70. Miss. Rpts. 1948, 1949; Takahashi and Ripperton, Hawaii Rpt. 1948–50.
71. Nevens and Harshbarger, Ill., Jour. Dairy Sci., 23, 1940, pp. 1023–1029.

CHAPTER XVIII

THE HAY AND PASTURE GRASSES—THE CEREALS FOR FORAGE—STRAW

I. The Grasses; the Cereals for Forage

560. The hay and pasture grasses.—The hay and pasture grasses are mostly perennials which thrive without yearly tillage, producing roughage of good. quality with little expense for labor. The grasses are also of great importance for building up the soil by adding humus. Moreover, they bind the soil together and prevent erosion because of the tremendous root systems. It has been estimated that in the top three inches of soil in a field of Kentucky bluegrass there are over 160,000 miles of roots per acre.[1]

The grasses are divided into two classes—the sod-formers and the non-sod-formers. The sod-formers, which spread by creeping rootstocks either above or below ground and make a smooth turf, include our most valuable pasture and lawn grasses, such as Kentucky bluegrass and Bermuda grass. The non-sod-formers, such as orchard grass, grow in tufts or bunches and increase only by seed or by stooling, except in the case of a few, such as timothy, which also increase to a limited extent by forming new bulb-like enlargements at the base of the stems.

The effect of various factors on the composition of pasture and hay crops has been discussed in Chapters XIII and XIV. Also, information is there given about the use and management of pastures and concerning haymaking.

561. Combinations for meadows and pastures.—A mixture of one or more grasses, combined with suitable legumes, is generally preferable to any single variety of grass for permanent pastures or meadows. Not only will the mixture provide a larger yield, but also the stand will be more permanent. A simple mixture, such as alfalfa or Ladino clover with a single grass, such as bromegrass, timothy, or orchard grass may be equal to or even excel a more complex mixture. Advice concerning the best mixture for local conditions can readily be secured from the county agricultural agent or the state college of agriculture.

For permanent pastures the chief reliance should be placed on those plants that are high-yielding and also permanent. However, some grasses of this type, such as Kentucky bluegrass, require time to become well established. It is, therefore, advisable to include with such a grass quick-growing plants to furnish forage while the slower-developing kind is becoming established. For this reason, such species as timothy and alsike clover are very often added to pasture mixtures, although these plants will usually be crowded out in a few years by the longer-lived kinds.

562. Composition and nutritive value of the grasses.—Before we consider the characteristics and usefulness of the various grasses, it is important to understand their general composition and nutritive value. While differing to some extent in palatability and feeding value, most of the grasses resemble each other in composition and value.

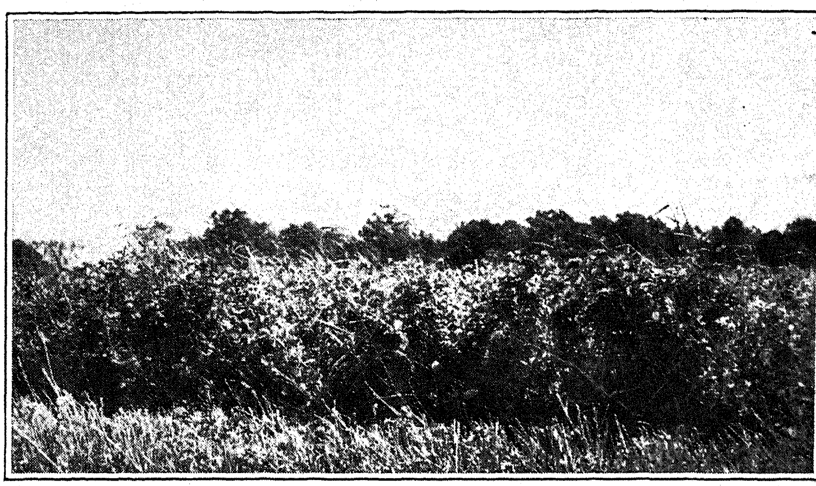
The great differences in composition and nutritive value of grasses at young stages of growth and when they are more mature have been emphasized in Chapters XIII and XIV. On the dry basis, young grass is far higher in protein, minerals, and vitamins than more mature grass, and it is much lower in fiber and especially in lignin (which has little feeding value). Young grass therefore is much higher in total digestible nutrients or net energy than at later stages.

When grass becomes mature and weathered, it resembles straw in composition and feeding value. It is poor in protein, it is low in digestibility, it may be very deficient in phosphorus, and it has practically no carotene.

The great changes in composition as grass advances in growth greatly affect the palatability and nutritive value of grass hay and of pasture forage. Early-cut grass hay from well fertilized fields may equal or approach legume hay in value for dairy cows and beef cattle, except that it is lower in protein and therefore a greater amount of protein supplement is needed with it. Such early-cut grass hay is even satisfactory for sheep, if fed with some legume hay or silage. On the other hand, late-cut grass hay is a poor roughage for milk cows and still poorer for sheep. When such hay must be used up, it is most suitable as part of the roughage for wintering beef breeding cows, stocker cattle, or well-grown dairy heifers, or for feeding horses or mules.

Even early-cut grass hay cured in the ordinary manner is not a satisfactory substitute for alfalfa or other legume hay in feeding swine or poultry. However, dehydrated very young forage from grass or small grains can be used for this purpose. (**416, 586**)

When grass hay is fed as the only roughage or with other non-legume roughage to dairy cattle, beef cattle, sheep, brood mares, or growing colts, ground limestone or some other calcium supplement should be supplied, unless one knows that the hay has plenty of calcium. The amount of protein supplement that is required to balance such a ration will ordinarily furnish sufficient phosphorus.



A HEAVY CROP OF MIXED LEGUMES AND GRASS

Such mixtures provide excellent hay or silage, much richer in protein than that from grass alone. (From New York State College of Agriculture.)

Mixed grass-and-legume hay is decidedly superior to grass hay, wherever legume hay crops thrive. Not only will a suitable combination usually produce much more hay per acre than grasses alone, but also the hay will have a higher value. It will be considerably richer in protein, both because of the higher protein content of legume forage and also because grasses themselves usually contain more protein when grown in combination with legumes. Mixed hay is also higher in calcium and in vitamins than grass hay, and it will usually be more palatable as well. Mixed hay high in the proportion of legumes is best for dairy

cattle, beef cattle, and sheep, while that lower in legumes is most suitable for horses and mules.

Young, actively-growing grass pasture on fertilized fields is good for all classes of stock, even swine or poultry. However, wherever pasture legumes thrive, a combination of grasses and a suitable legume will produce much more feed and over a longer period. Also, the forage will be more nutritious, because of its much higher content of protein, minerals, and vitamins. Grass pasture practically never produces bloat in cattle or sheep, and trouble with bloat from legume pasture may largely be avoided by combining legumes with grass. For swine and poultry, pure legume pasture or a combination high in legumes is generally greatly superior to grass pasture.

563. Grass hay and mixed hay for dairy cattle.—Timothy or other grass hay of the usual quality is much inferior to legume or mixed hay for dairy cows. It is not only of decidedly lower value, but also the cattle will not eat as much of such grass hay as they will of legume hay. Consequently, in order to secure good milk production on grass hay, cows must be fed a considerably greater amount of concentrates than is needed with good legume hay. Grass hay of average quality is unsuited for young dairy calves.

Early-cut grass hay, especially from fields well fertilized with manure or commercial nitrogen fertilizer, can be used successfully as a substitute for legume hay in feeding dairy cattle during the winter. Such timothy or other grass hay will generally be considerably higher in protein than grass hay of the usual sort, and it is also soft and well liked, instead of being harsh, stemmy, and unpalatable.

Unless timothy or other grass hay is early-cut and of excellent quality, the milk yield will be decidedly lower when it is fed to cows as the only roughage than when better hay is fed.[2] This is true even when the ration is balanced with protein supplements. If grass hay is fed in an unbalanced ration, without protein supplements, then the yield of milk will be seriously reduced.[3]

When timothy or other grass hay must be fed to dairy cows without any legume hay, it will give better results if silage is used as part of the roughage. Also, one should be careful to feed a calcium supplement, unless he is sure it is not needed.

When there is a very limited amount of legume hay for the herd, it is best to give the cows one feed of legume hay a day, rather than to feed it more liberally for a time and use it all up during a part of the winter. Foresight is needed to store the various kinds and qualities of hay in the barn so this will be possible.

Feeding some legume hay to cows during the dry period is very important. At this time they have the greatest ability to regain the store of calcium and phosphorus which may have been lost from their bodies during high milk production. (1037)

564. Early-cut versus late-cut grass hay for dairy cows.—The great difference between the value for dairy cows of early-cut grass hay from well fertilized fields and late-cut, poor-quality grass hay has been clearly proved in feeding experiments. In New York trials one group of cows was fed throughout each winter on early-cut, well fertilized timothy hay, along with corn silage and a suitable concentrate mixture.[4] Another was fed good alfalfa hay, corn silage, and a concentrate mixture enough lower in protein to provide the same percentage of protein in each ration. Minerals were added to each ration.

The timothy-hay ration produced as much milk as the alfalfa-hay ration and maintained the live weights of the cows just as well. Also, the cows liked the timothy hay fully as well as the alfalfa and refused no larger proportion, the refuse of both kinds of hay being less than 2 per cent. Similar results were secured in a Wisconsin trial and another New York experiment.[5]

In strong contrast to these results are those secured with late-cut, poor-quality timothy hay in experiments by the United States Department of Agriculture.[6] Cows broke down on the average

in about a year and a half and died or became sterile, when fed such timothy hay and a suitable concentrate mixture, without any pasture but in some cases with a limited amount of corn silage. Because of the lack of carotene in the hay, the calves from cows thus fed were born dead, or else weak and blind. The vitamin content of the milk was so low that it was impossible to raise calves from well-fed cows on the vitamin-deficient milk, unless a vitamin A supplement was added. In contrast to these results, a cow kept on only grain and good timothy hay (United States Grade No. 1) for 4 years gave birth during this period to 3 normal calves.

The cows fed poor-quality timothy hay showed a great desire to steal alfalfa hay from their neighbors fed alfalfa hay, and when they were fed alfalfa in addition, the disasters were prevented. It was surprising that although cows were successfully fed on good alfalfa hay as the only roughage for similar lengths of time, they showed an eagerness for hay of some other kind. The best results were secured when high-quality alfalfa hay and timothy hay were both fed, so the cows could eat as much as they wished of each.

It should be pointed out that the conditions of these experiments were unnatural and most severe, since the cows had no pasture or other fresh green feed at any time. Though poor-quality grass hay is unsatisfactory for dairy cows, it will not produce such disastrous results when fed as the only or the chief roughage during the usual barn-feeding period.

The great differences between early-cut and late-cut grass hay are also clearly shown by New Hampshire metabolism experiments with dairy cows.[7] Timothy hay cut before bloom furnished 44 per cent more net energy than did that cut after the seed had formed. While only about one-third of the protein in the late-cut hay was digestible, about 60 per cent of that in the early-cut hay was digested. When supplied as the only feed, the late-cut hay furnished barely enough nutrients for maintenance, but the early-cut hay supplied sufficient for maintenance and the production of 8 to 10 lbs. of milk a day.

565. Grass hay for beef cattle.—While grass hay of the usual quality is much less valuable than legume hay for beef cattle, such hay will produce satisfactory results when it is properly used. A sufficient amount of protein supplement should be provided to balance the ration, and if little or no legume hay is fed, ground limestone or some other calcium supplement should be supplied.

Grass hay can be used best when fed with a limited amount of legume hay or else with silage. Also, it more nearly approaches legume hay in value for wintering beef cows or stocker cattle than for fattening cattle or for wintering calves. Early-cut grass hay from well-fertilized fields is of decidedly higher value than late-cut hay from worn-out meadows.

When good-quality grass hay is fed to fattening cattle with proper protein and calcium supplements, the gains may be as rapid as with legume hay. However, much more protein supplement will be needed to balance the grass-hay ration and generally more feed will be required per 100 lbs. gain. The grass hay will therefore be worth considerably less per ton than legume hay.

For example, in Oklahoma tests fattening calves fed prairie hay as the only roughage in a properly supplemented ration made as good gains as others fed alfalfa hay, but the prairie hay was worth only 39 per cent as much per ton as the alfalfa.[8] In similar Kansas trials prairie hay, fed along with sorghum silage and grain and supplemented with cottonseed meal and ground limestone, was worth fully two-thirds as much as alfalfa hay.[9]

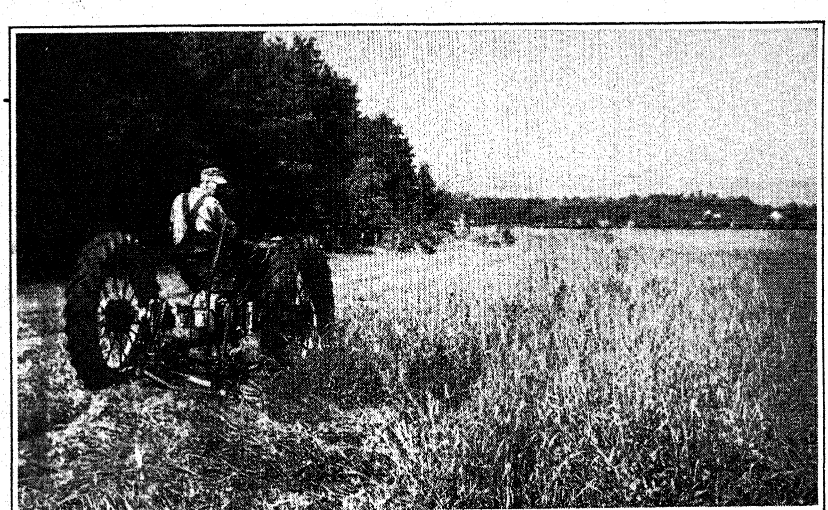
566. Grass hay and mixed hay for sheep.—Pure grass hay is much less satisfactory for sheep than it is for beef cattle, even when supplemented with protein and calcium. Far better results are secured with mixed legume-and-grass hay, or when grass hay is fed along with some legume hay.[10] For example, in an Ohio trial with fattening lambs timothy hay was decidedly inferior to alfalfa hay

as the only roughage, but a combination of equal amounts of the two kinds of hay was only slightly inferior to the alfalfa hay.[11]

Early-cut grass hay is much better than late-cut hay for sheep. Thus, satisfactory results were secured when timothy hay cut in early bloom was fed with corn silage and with 0.8 ounce of ground limestone per head daily and plenty of protein supplement to pregnant ewes in Ohio trials.[12] On the other hand, when late-cut timothy replaced the early-cut hay as the only roughage, the ewes lost weight, became thin and weak, produced lambs lacking in vigor, milked poorly, and showed a decided tendency to shed the fleece because of weakened wool fibers.

567. Grass hay and mixed hay for horses and mules.—For work horses or mules and for light horses, good timothy hay or other grass hay is unexcelled and is taken as the standard with which other hays are compared. Grass hay has this high place in feeding work stock and mature horses in general because it is much less apt to be dusty or moldy than is legume hay. Also, the protein requirements are low for mature horses, except brood mares nursing foals.

For growing colts and for brood mares, well-cured mixed grass-and-legume hay or legume hay is better than pure grass hay, because of its higher content of protein, calcium, and vitamins.



CUTTING A HEAVY CROP OF MIXED TIMOTHY AND LEGUME HAY

Mixed timothy and clover or timothy and alfalfa hay produces a much higher yield and has a greater value for all stock, except horses, than does pure timothy hay. (From New York State College of Agriculture.)

568. Timothy.—In this country timothy (*Phleum pratense*) is by far the most important hay grass and also the most widely-used pasture grass for short-time pasture seedings. It is distinctly a northern grass and does not thrive where the summers are too hot and humid. Timothy is usually seeded in small grain, and a mixture of timothy with clover or alfalfa is commonly used instead of the grass alone. Such a mixture produces a considerably greater yield, and even more important, the mixed hay has a higher value for all classes of stock except mature work horses and mules or light horses.

If conditions are favorable for clover, the first cutting of hay, the year after seeding a combination of timothy and clover, will be largely clover. A still

larger proportion of the second cutting will be clover, for timothy does not produce much second crop, unless cut extremely early. Except in a few districts, most of the clover, especially red clover, dies at the close of the second year. The decaying clover roots then furnish nitrogen for the timothy, so that a larger yield of the grass is obtained the next season than would otherwise be the case. On many farms timothy is regularly used for pasture for a year or more after it has been cut for hay one or two seasons.

A field is often left in timothy for too many years. When this is done, the yield will usually become too low to be profitable, unless the meadow is well fertilized with manure or other fertilizer containing nitrogen, as well as phosphorus. Sometimes farmers continue to speak of hay as "mixed hay" or "clover-and-timothy hay" when practically all the clover has died out, and there is actually only a trifle of clover.

Though numerous experiments have shown that clover or alfalfa hay is greatly superior to the usual kind of timothy hay, timothy continues to be popular for the following reasons: It thrives on soil that is too acid or too poorly drained for alfalfa or red clover. The seed is cheap and generally of high quality. A good stand of timothy is quickly established, and it usually holds well in meadows. The grass seldom lodges, it may be harvested over a longer period than most grasses, and it is easily cured into bright, clean hay which is free from dust and which can be handled with little waste.

Experiments have shown clearly that when quality and yield of hay are both considered, it is best to cut timothy not later than early bloom, for all classes of stock except horses and mules.[13] If the crop is cut later than early bloom, the yield of hay may be a trifle larger, but the quality is much poorer. Also there will be less second growth, which is excellent for late summer and fall pasture. The early-cut grass is a little more difficult to cure than that cut late, but this fact is much more than offset by the higher feeding value of the hay. Continued cutting of timothy before bloom is apt to injure the stand.

For work horses and mules and for saddle and driving horses, hay cut in full bloom is preferable, for that cut too early may be unduly laxative. However, even for horses and mules the cutting should not be delayed much after full bloom, or the grass will become tough and woody. Much more timothy hay is cut too late than too early.

Where fields in the regular crop rotation are used for pasture, timothy is usually the most common pasture grass in the area where it thrives. At early stages of growth timothy pasture is liked even better than bluegrass by stock.

Ordinary timothy is gradually crowded out of permanent pastures by the sod-forming grasses. Pasture-type varieties have therefore been developed which last better in pastures. Varieties have also been bred which are both later and earlier than ordinary timothy.

569. Timothy and timothy-legume hay for horses.—Except for mature horses and mules, mixed timothy-and-clover or timothy-and-alfalfa hay is superior to pure timothy hay or hay from other grasses. For mature horses and mules, timothy hay is the standard roughage with which others are compared. Timothy hay has this high value for such horses and mules because it is usually freer from dust and mold than is legume hay. Also, these animals need but relatively little protein, calcium, and vitamins. Therefore legume hay, which is much richer than timothy in these nutrients, does not have the same advantages for them that it does for dairy cows, growing animals, or sheep. For colts and brood mares mixed timothy-and-legume hay is superior to pure timothy hay, on account of its higher content of protein, calcium, and vitamins.

570. Timothy hay for other stock.—It has been shown earlier in this chapter that early-cut timothy hay from well-fertilized land is a satisfactory hay for dairy cows, when legume hay or mixed hay is not available. (564) On the other hand, late-cut timothy hay or that which

is otherwise of low quality is a poor feed for milk production.

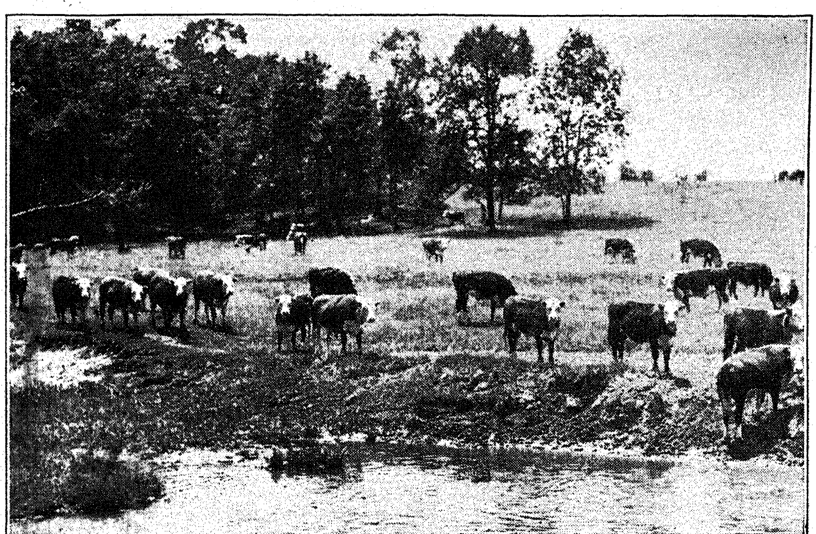
Timothy hay grown on fertile soil and cut early is also much better than ordinary timothy for beef cattle. Steers which were wintered on only timothy hay which had been grown on well-fertilized land gained 1.2 lbs. a day in a Minnesota test, while others fed ordinary timothy gained only two-thirds as much.[14] When ordinary timothy hay is used for beef cattle, one must feed considerably larger amounts of grain and also of protein supplement than are needed with better roughage.[15]

The very unsatisfactory nature of late-cut timothy or other grass hay for sheep has been emphasized earlier in this chapter. (**566**) Though early-cut timothy hay of good quality can be used in sheep feeding, legume hay or mixed hay is decidedly superior.[16]

571. Kentucky bluegrass.—Kentucky bluegrass (*Poa pratensis*), commonly called merely bluegrass or June grass, ranks first as a pasture and lawn grass in the northern half of the United States, except where the climate is too dry. It requires a well-drained, fertile soil, and is not so well suited to wet soils as is red top. The combination of bluegrass and white clover makes an especially good permanent pasture. Therefore bluegrass should generally be grazed closely enough to encourage the growth of white clover.

The fact that bluegrass is one of the richest of grasses in protein helps explain the fondness for it shown by stock. Before heading out in the spring, bluegrass usually contains nearly 20 per cent protein, if dried to a hay basis. Also, when the grass is kept actively growing by proper fertilization and management of the pasture and is not permitted to head out, the percentage of protein will be nearly as high later in the season. On the other hand, bluegrass in bloom or later is low in protein and high in fiber. While bluegrass is much less nutritious at the late stages of growth, even then it is grazed more readily by stock than most other mature grasses.

In Pennsylvania experiments bluegrass at a good pasture stage excelled timothy, bromegrass, orchard grass, al-



BEEF CATTLE FATTENING ON BLUEGRASS PASTURE

In the northern half of the United States, Kentucky bluegrass is by far the most important grass in permanent pastures.

falfa, and Ladino clover in amount of total digestible nutrients or metabolizable energy per pound of dry matter.[17] In Kentucky pasture trials with sheep, bluegrass ranked high among various pastures in daily intake of total digestible nutrients.[18]

Bluegrass starts growth early in spring and soon provides excellent pasturage. It is a cool-weather grass and becomes dormant in hot, dry weather. Therefore it often furnishes but little forage in midsummer. It starts growth again with the coming of fall rains and furnishes first-rate fall pasturage.

There is thus generally a decided shortage of feed on bluegrass pastures in midsummer. Plans should accordingly be made to furnish plenty of other forage at this time by one of the methods discussed earlier. (382) This is especially important in the case of milking cows, or else they will fall off seriously in production. Sometimes a bluegrass pasture is stocked rather lightly in the spring, so there will be some grass left to provide feed later. However, such mature growth is not very palatable or nutritious. Also, if the bluegrass is allowed to grow up in this manner, the shade will tend to kill out the white clover, which is a most valuable part of the best permanent pastures.

Old, run-down bluegrass pasture can be greatly improved through "renovating" it by disking, applying lime and fertilizer, and reseeding to legumes which are suited for pasture in the particular locality. (379) The legume-bluegrass combination will produce considerably more total forage during the season. Still more important, it will furnish much more feed in midsummer.

For swine, bluegrass furnishes excellent spring and fall pasture, but alfalfa, red clover, or rape is far superior in midsummer. Several experiments have been conducted to compare bluegrass with these pastures for swine.[19] Generally, pigs have gained less rapidly on bluegrass than on such pastures as alfalfa, red clover, or rape. Even more important, considerably more grain and other concentrates have been required per 100 lbs. gain by the pigs on bluegrass. In certain tests where bluegrass pasture had a considerable proportion of white clover, it more closely approached the better pastures. Since bluegrass and other grasses are lower in protein than alfalfa, clover, or rape, a somewhat larger amount of protein supplement is needed to balance the ration of pigs fed grain on grass pastures.

Because of its low, spreading growth, bluegrass does not make a good yield of hay. If cut in early bloom, the hay is nearly equal to timothy. However, most bluegrass hay, such as is cut along the roadside after the grass has gone to seed, is of low feeding value.

572. Red top.—Red top (*Agrostis alba*) is suited to a wider range of climate and soil than any other cultivated grass. It ranks next to bluegrass in importance as a pasture grass in the United States. A couple of years after seeding it forms a close, smooth sod, almost as dense as bluegrass. Red top is excellent for damp land, and yet it stands considerable drouth. It endures on poor uplands and on soils too acid for most other grasses, and it may be grown farther south than timothy or bluegrass. It does not respond well to fertilization. Red top is an important hay grass in New England.

Red-top pasture or hay is only fair in palatability. Therefore red top is usually grown only where better-liked grasses do not thrive, and it is commonly seeded with other grasses and the clovers.

573. Bromegrass.—Smooth bromegrass (*Bromus inermis*), usually called bromegrass or merely "brome" in this country, has become one of the most important grasses in the northern and central states for use in legume-grass mixtures for pasture, hay, or silage. (378, 382, 469, 477) It has its highest value in most areas when grown in such a mixture.

Brome is one of the most palatable of grasses and it retains its palatability and nutritive value at much later stages of growth than most grasses.[20] It starts growth early in the spring and continues

well during the summer, because of its drouth resistance. It produces much more aftermath than timothy. Brome will not tolerate continuous close grazing, resembling alfalfa in this respect. It is deep rooted and does best on a well-drained fertile soil.

Bromegrass is slower than timothy to become established after seeding. This is not a disadvantage when it is grown with alfalfa, for it permits the alfalfa to get well started first. When grown alone, bromegrass usually declines greatly in productivity after 3 or 4 years, because of a lack of nitrogen, for it is a heavy feeder. It was formerly thought that this was caused by a "sod-bound" condition, but the vigor of the stand can be restored by applying manure or a commercial nitrogen fertilizer. This condition does not occur when bromegrass is grown with alfalfa, as the legume plants help furnish the nitrogen needed by the grass. Even after the alfalfa dies out, bromegrass continues to thrive for a year or two, because of the nitrogen supply left by the alfalfa.

Bromegrass makes good hay when cut when in bloom or even a little later, but legume-brome hay is, of course, decidedly superior for most stock.

Brome-legume pasture ranks high in yield and value. Even for pigs or poultry, brome alone provides better pasture than most other tall grasses.[21]

Except in the extreme northern part of the United States and in Canada, southern strains of bromegrass developed from Nebraska southward, are decidedly more vigorous and productive than the northern strains. Certain varieties have been developed which spread less vigorously and crowd out alfalfa less.

574. Bromegrass meal.—Bromegrass meal, either dehydrated or field-cured, and made from brome cut before heading, can be used like alfalfa meal as a vitamin supplement for swine.[22] Such bromegrass meal may have as much carotene as alfalfa meal.

575. Orchard grass.—Orchard grass (*Dactylis glomerata*) is a long-lived perennial that grows in nearly every state of this country. It is called cocksfoot in England. Orchard grass does not stand cold winters as well as timothy, but it can endure more heat in summer and does better on soil of low fertility. It is grown most widely in a broad belt south of the middle of the corn belt. Here it is used as a substitute for timothy, and is usually seeded with clover. Ripening two weeks before timothy, it fits in well with red clover. North of this belt, timothy is superior, chiefly because it is hardier and the seed is much cheaper.

Orchard grass grows in bunches or tufts, forming an uneven sod, and hence should be sown with clovers or other grasses, both for hay and for pasture. It does better in partial shade than most grasses and owes its common name to this characteristic.

Orchard grass is used mostly for pasture, especially in combination with a legume, such as alfalfa, Ladino clover, or annual lespedeza. It starts growth early in the spring, is high yielding, endures drouth well, and continues growth late in the fall. It does not stand continuous close grazing, but it is not palatable if it grows up tall, for it becomes very coarse and woody. Therefore the pasture should be stocked heavily enough to keep the rapidly-growing grass from heading out, and it should be clipped, if necessary.

Orchard grass is excellent in a mixture for a pasture which is not too large, and which is to be grazed heavily early in the season. It should not generally be included in a mixture for seeding a large acreage of pasture, for it may then be difficult to get it grazed down in the spring before it becomes unpalatable. In Maryland trials orchard grass-Ladino clover pasture was excellent for beef cattle.[23] Orchard grass is less useful for sheep pasture. In Kentucky tests of several pastures it ranked low in amount of total digestible nutrients consumed daily by sheep.[24]

While late-cut orchard grass makes poor, woody hay, that cut not later than early bloom is equal to timothy. Orchard grass furnishes more second growth than any other hay grass adapted to northern conditions.

Early-cut orchard grass-legume mixtures make good hay-crop silage.

576. Bermuda grass.—In the southern states this sod-forming grass (*Cynodon dactylon*) is the most important pasture grass and also lawn grass. It does not survive northern winters. Common Bermuda grass does not grow tall enough for hay, except on the more fertile soils, but taller varieties have been developed which provide both pasture and hay. Of these varieties Coastal Bermuda grass is most widely grown. It produces more growth in the fall, remains green longer, and is more resistant to leaf spot disease. Suwanee Bermuda grass, another tall-growing variety, is especially well adapted to sandy soil.

Bermuda grass is commonly propagated by planting sprigs (pieces of the rootstalks). Common Bermuda is sometimes seeded, but Coastal and Suwanee produce few viable seeds and must be propagated with sprigs or pieces of sod.

Bermuda grass forms a dense sod but does not provide pasture over so long a season as does carpet grass or Dallis grass. It is late in starting in the spring and ceases growth with the first frosts in fall. Bermuda provides the best pasturage when closely grazed, as otherwise it becomes tough and wiry. It stands drouth well.

If possible, Bermuda should be grown in combination with a legume—lespedeza for summer pasture or crimson clover, white clover, or bur clover for winter pasture when Bermuda is dormant.

Bermuda hay is about equal to timothy in value. By heavy nitrogen fertilization of Coastal Bermuda large yields of hay can be secured, much higher in protein than ordinary grass hay. (372)

577. Prairie grass and hay; wild hay.—The value of native or wild grasses for pasture or hay varies widely in different regions, depending on the climate, the soil, and the kinds of grasses. The native grasses are of especial importance in the western states, where they furnish the chief forage on the ranges and also much of the hay. Among the leading species of native grasses on the western prairies are the grama grasses, the wheatgrasses, the bluestems, and buffalo grass.

The importance of wild hay, including prairie and marsh hay, in the United States is shown by the fact that the acreage of such hay is about two-thirds that of alfalfa. The total amount of wild hay produced is, however, only about one-fourth as great as the production of alfalfa hay, because the average yield is less than 1 ton per acre.

The grasses on the western mountain meadows and on the upland prairies are generally highly nutritious and palatable when actively growing. They then furnish excellent pasturage and also make hay about equal to timothy, when the growth is tall enough to be cut.

On the other hand, grass which has matured may have a very low feeding value, because of weathering and leaching, as has been pointed out previously. (362) Such pasturage may even produce nutritional trouble, owing to lack of protein, carotene, or minerals. If there is little or no rain after the grass matures, there is much less loss through weathering, and the dried mature grass may furnish satisfactory feed, except that it will be low in carotene (vitamin A value).

In certain forest range areas of the southeastern Coastal Plain, tall-growing reeds, or switch cane, furnish most of the feed for beef cattle, even during the winter. North Carolina experiments show the advisability of feeding a protein supplement to beef cows wintered on reed pasture, because the forage is then very low in protein.[25]

Prairie hay cut when still green is similar to timothy hay in composition and feeding value, although usually somewhat higher in protein. Since prairie hay is readily cured and the weather in the prairie region is usually good for haymaking, prairie hay harvested at a reasonably early stage has a good content of carotene. In Oklahoma experiments dairy cows remained healthy when fed continuously for 3 years only good prairie hay with cottonseed meal, which supplies no carotene.[26] In other Oklahoma tests only 8 lbs. of good prairie hay a day

as the only source of carotene was sufficient for normal reproduction.[27]

Prairie hay differs widely in value, however. Arkansas experiments show that sometimes it may be unsatisfactory as the only roughage over long periods.[28]

Much prairie hay or other native hay is cut far too late to have good feeding value. Often it is not cut until late fall when farm work is less pressing. Experiments have shown that reasonably early cutting, not later than mid July, makes much better hay than such late cutting and also usually gives a greater yield, including the aftermath.[29]

The great difference in value of prairie hay due to time of cutting is shown by Nebraska experiments.[30] Beef calves wintered on only prairie hay gained 0.29 lb. a day on hay cut reasonably early, gained only 0.10 lb. a day on hay cut in early August, and lost 0.18 lb. a day on hay cut in September.

Marsh hay is usually decidedly inferior in value to hay from upland meadows, though bluejoint (*Calamagrostis Canadensis*), cut before maturity, nearly equals timothy in value. Marsh hay may often be used satisfactorily for horses and mules, especially those which are idle or not working hard. It is ordinarily not well suited to dairy cattle or sheep. In a recent North Dakota trial in which lambs were fattened on mixtures of chopped hay and concentrates, the gain in weight was satisfactory when chopped marsh hay replaced half the alfalfa hay, but considerably more feed was required per 100 lbs. gain.[31]

The marsh hay of the western mountain districts, though consisting largely of sedges and rushes, is usually of higher value than such hay in the eastern states.

578. Prairie hay for dairy cattle.—In the preceding discussion it has been shown that prairie hay of first-rate quality can be used successfully as the only roughage for dairy cows, even for long periods. In 4 Oklahoma tests good-quality prairie hay (grading as U.S. No. 1, extra green) was compared with No. 1 alfalfa hay as the only roughage for cows fed the usual amounts of concentrate mixture in addition.[32] To balance the ration in protein content, the concentrate mixture in the prairie-hay ration had 20 per cent protein, while a mixture with only 15 per cent protein was fed with the alfalfa hay. On prairie hay the yield of fat-corrected milk was 25.8 lbs. per head daily, in comparison with 26.4 lbs. on alfalfa hay. Taking into consideration the additional cost of the greater amount of protein supplements needed with it, prairie hay was worth on the average 87 per cent as much per ton as the alfalfa hay.

In another Oklahoma test good prairie hay was fairly satisfactory as the only roughage for dairy calves.[33]

579. Prairie hay for beef cattle.—In the western range areas beef cattle are often wintered on prairie hay as the chief feed.[34] Early-cut prairie hay alone will usually furnish plenty of protein for wintering yearling or older cattle or beef cows. When calves are wintered on prairie hay of usual quality as the only roughage, they will need 0.5 to 1.0 lb. of protein supplement per head daily and perhaps a little grain to make as good gains as when fed alfalfa hay alone. In Oklahoma trials prairie hay, properly supplemented, was worth about three-fourths as much per ton as alfalfa hay for wintering calves.[35] In another Oklahoma test it took 1.8 tons of sorghum silage to equal 1 ton of prairie hay in feeding value.[36]

580. Prairie hay for sheep.—Good prairie hay can be used satisfactorily as the only roughage for wintering breeding ewes, if they are fed both protein and calcium supplements.[37] It is decidedly unsatisfactory for wintering ewes or other sheep, when it is the only feed or when fed with grain, without protein and calcium supplements.[38]

Prairie hay, even of good quality, is worth considerably less than legume hay as roughage for fattening lambs, though properly supplemented with protein and calcium. For example, in Minnesota tests, although lambs made satisfactory gains on prairie hay, shelled corn, linseed meal, and ground limestone, the prairie hay was worth only 59 per cent as much per

ton as alfalfa hay.[39] Very unsatisfactory results have been secured when prairie hay was not supplemented with protein or calcium.

Lambs fattened on legume hay as the only roughage will usually make considerably more rapid gains than those fed prairie hay. In Oklahoma experiments the feed allowed lambs on an alfalfa hay ration was restricted a little, so that the gains on prairie hay and on alfalfa hay would be equal.[40] This was done so as to determine the approximate net energy value of prairie hay in comparison with that of alfalfa hay. (**81**) Thus fed, the value of the prairie hay was 87 per cent that of alfalfa hay. When fattening lambs are full-fed for rapid gains, there would, of course, be a greater difference in favor of alfalfa hay.

581. Prairie hay for horses and mules.—Prairie hay of good quality is a first-rate roughage for horses and mules, as it is free from dust and is well liked by them. It can be used in the same manner as timothy hay.

582. The small grains for forage.—In certain regions the small grains are very important forage crops, being used for hay or pasture and occasionally as soiling crops or for silage. In the Pacific Coast states the small grains are important as hay crops, ranking next to alfalfa in acreage. Barley and wheat are the chief grains used for hay in this district, and much hay is also made from volunteer stands of wild oats. The use of straw for feeding is discussed later in this chapter. (**620–624**)

While the small grains are relatively low in protein at a hay stage, they are very rich in protein at the early stages of growth. For example, green rye, wheat, or oats before heading out will contain 20 per cent or more of protein, if dried to the same moisture content as hay. Such young forage is also very rich in carotene and the B-complex vitamins.

583. The small grains for pasture.—In the southern states and also in the prairie winter-wheat district, winter grain is widely used for pasture from fall to spring, whenever the weather is suitable. Farther north, winter grain is a valuable pasture for late fall and early spring, thus extending the usual grazing season. Spring-sown oats or barley are sometimes used for late spring and early summer pasture.

In the North rye is generally superior to wheat for fall and spring pasture, because it is more hardy. Farther south, wheat is preferable in some sections. In the southern states winter oats or barley may be better than rye or wheat for winter pasture. In the portion of the winter-wheat belt from Kansas southward and in the South, winter grain can be grazed moderately from fall to early spring without much decrease in grain yield, if the growth by fall is normal. Sometimes such pasturing even benefits the grain yield, as it prevents lodging. Care must be taken not to pasture the grain when the field is so wet that the stock will injure the crop by trampling.

Winter pasture on small grain or mixed small grain and legumes aids greatly in reducing the cost of milk production in the southern states. Not only does such pasture provide cheap feed, but also the milk yield is increased and the vitamin A content of the milk is kept much higher than when the cows are on permanent pasture in winter or are barn fed.[41]

Green rye of most varieties may give a marked flavor to milk, unless the cows are pastured on it for only 2 or 3 hours after milking. Balbo rye apparently has little such effect.[42]

The importance of winter grain pasture in reducing the cost of beef production is well shown by South Carolina experiments in which rye pasture was compared with sorghum silage as the chief feed for wintering steers.[43] The cost of harvested feeds averaged only 80 per cent as much per head for the steers pasturing rye as for the others. In an Oklahoma test the feed cost of harvested feeds, per 100 lbs. gain, was only 60 per cent as much for lambs grazed on wheat pasture for 2 months and then finished on alfalfa hay and corn, as it was for

lambs fed alfalfa hay and corn in dry lot from the start.[44]

Winter rye and winter wheat provide excellent pasture for swine in late fall and early spring in the northern states, rivalling or excelling bluegrass in this respect.[45] In the central states these winter grains will also furnish considerable forage during the winter, if there has been a good growth by the time cold weather comes on in the fall. In the South winter grains will provide good pasture for swine from fall until spring.[46]

Since young small-grain plants are rich in protein, on the dry basis, such pasture will save protein supplements in the same manner as alfalfa or rape pasture. Pigs on excellent small-grain pasture may make satisfactory gains when fed only corn and minerals. However, it is generally best to add a small amount of an efficient protein supplement, unless the pasture is unusually good.

In the grain-growing districts of the Pacific Northwest, where the summers are dry, ripe small grain is sometimes hogged down, the pigs being turned in when the crop is nearly ripe.[47] In humid districts it is most economical to harvest the crop and feed the threshed grain.[48]

Especially on the grain farms of the West, stubble fields are important in economical pork production. Where the grain is harvested by means of a combine thresher, a considerable amount may be left ungarnered. Many farmers have hog-fenced their fields and turn pigs on the stubble to glean the scattered heads of grain. Gains made on such waste are almost clear profit.

Occasionally, stock grazing winter wheat or oats in the southern plains states are affected by "wheat poisoning." This is similar to or the same as grass tetany, which has been discussed in Chapter VI, where methods of preventing the trouble and a treatment have been suggested. (179)

584. Hay from the small grains.—Well-cured hay from the small grains resembles good timothy hay in composition and feeding value, and it may be used similarly. On the Pacific Coast cereal hay is used extensively for horses and mules. It is satisfactory as the only roughage for mature horses and for wintering beef breeding cows. For dairy cattle, for growing or fattening cattle, or for sheep, it should be fed, if possible, as only part of the roughage, along with legume hay or silage.

A sufficient amount of protein supplement should be used to balance the ration, for cereal hay is low in protein. Also, it is wise to supply a calcium supplement when grain hay is fed as the only roughage, or with such non-legume roughage as corn or sorghum silage or fodder.

Oats or barley make better hay than wheat, though barley hay may sometimes be objectionable because of the beards. Rye hay is least desirable, as it is coarse and lacks palatability.

In the northernmost states, where field peas thrive, a mixture of oats and peas is sometimes preferred to oats alone for hay, as such hay is more palatable to stock and considerably richer in protein. In the South, combinations of small grain with vetch or crimson clover are often used.

The value of hay from the small grains in comparison with alfalfa hay or mixed hay differs considerably, depending on the quality. In some tests oat hay or wild oat hay has been equal or nearly equal to alfalfa hay for beef cattle, while in another trial oat or barley hay was inferior to mixed clover-timothy hay for beef cows.[49] For wintering or fattening calves, a combination of half alfalfa hay and half grain hay is much better than grain hay as the only roughage.[50]

Grain hay should not be used as the only roughage for sheep, except in emergency. In Oregon experiments such a ration resulted in many lambs being born weak.[51] Also, chopped grain hay was inferior to alfalfa hay as the only roughage for fattening lambs.

The small grains should be cut for hay while the leaves and stems are still green, or the hay will be strawlike and low in palatability. In the semi-arid districts good hay can be made at a little later stage of maturity than in humid regions. Small-grain hay cut in the soft-

dough stage was higher in digestible nutrients in tests in eastern Washington than earlier-cut hay, because of the greater proportion of kernels it contained.[52] In humid regions oats and wheat should be cut in the milk stage, except for horses, for which the soft-dough stage is preferred. If rye is used for hay, it should be cut when in bloom. Cereals cut at an early stage cure rather slowly, and therefore care is necessary to get the hay sufficiently dry to prevent heating or molding after it has been stored.

In the semi-arid districts oat hay and other small grain forage have occasionally caused the death of stock from poisoning, because of an accumulation of nitrates in the plants during growth.[53] Most such trouble has occurred in cattle, though losses of sheep and horses have also been reported. (677)

585. The small grains for silage or as soiling crops.—If ensiled not later than the early-dough stage, the small grains make fair to good silage. The addition of about 40 lbs. of molasses or the use of some other preservative may be advisable to improve the quality. The crop should be run through the silage cutter and unusual care is necessary to tramp down the forage in the silo to force the air out of the hollow stems.

A green small-grain crop or such a mixture as oats and peas is satisfactory for feeding green as a soiling crop.

586. Dehydrated young cereals.—A dehydrated product is produced commercially from young oats or other small grain, harvested in the young stage of growth, before it begins to joint. This product, which is called dried cereal grass, or by the trade name of Cerophyl, is high in protein and carotene and rich in B-complex vitamins. It is used in the same manner as alfalfa meal or alfalfa leaf meal, chiefly for poultry.

587. Sudan grass.—Sudan grass (*Sorghum vulgare*, var. *sudanense*) is the most important annual hay grass in the United States. It is a near relative of the sorghums and of Johnson grass and resembles the latter, though it is taller and the leaves are broader and more numerous. However, it is distinctly an annual and entirely lacks the underground stems or rootstocks which make Johnson grass a serious pest in the South.

Sudan grass grows 4 to 8 feet high in cultivated rows, and 3 to 5 feet when sown broadcast. For so rank a grass, the stems are fine, being seldom larger than a lead pencil, and the leaves are soft in texture. It is adapted to the same conditions as the sorghums and is equally drouth resistant, but it is earlier and may be grown farther north. However, it is decidedly a warm-weather grass and does not thrive quite so far north as corn. Sudan grass yields best on fertile, well-drained soil, and needs a liberal supply of nitrogen.

Tift Sudan grass, developed by crossing Sudan grass with a sorghum, thrives better in the South, where leaf diseases affect ordinary Sudan grass seriously. *Sweet Sudan*, another sorghum hybrid developed in Texas, is also more resistant to disease and to chinch bugs. It has sweet stalks and is especially palatable to stock, but starts growth more slowly in the spring than ordinary Sudan grass. These varieties are apt to be higher than common Sudan in prussic acid, which is poisonous.

California No. 23 Sudan grass, popular in California, is taller, coarser, and more vigorous than common Sudan.

Piper, a new variety developed by the Wisconsin Station, has much less prussic acid than other Sudan grasses and is also high yielding and resistant to disease.

Where alfalfa, clovers, timothy, bromegrass, and orchard grass thrive, the chief use of Sudan grass is as a supplementary pasture crop or as an emergency hay crop. Sudan grass surpasses the millets in yield as well as in value of forage in most parts of the United States, and it has therefore largely displaced them there. In the Coastal Plain district of the southeastern states, pearl millet excels Sudan grass. On account of its drouth resistance, Sudan grass is one of the most valuable crops for the western

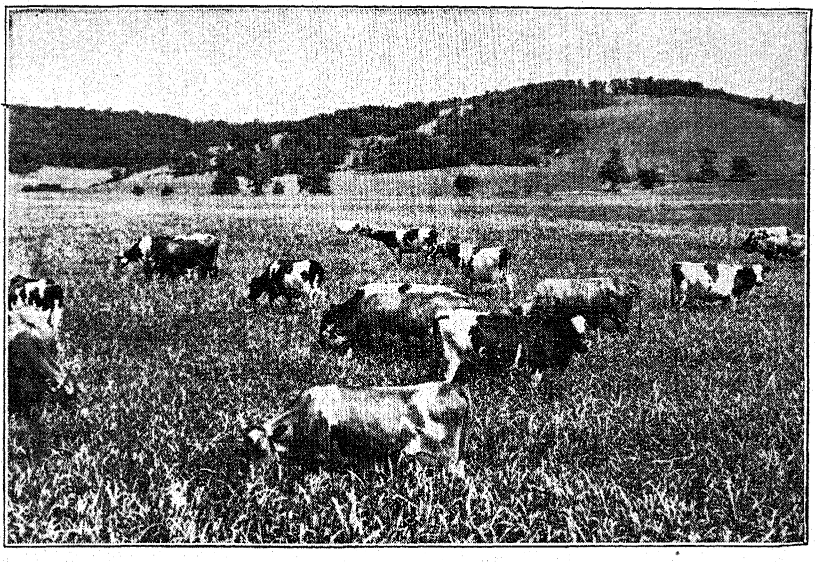
part of the plains region, from central South Dakota to Texas.

Sudan grass is one of the best annual pasture crops, especially to provide feed for the mid-summer period when permanent pastures are usually short. It is therefore particularly valuable for dairy cows, as it provides a large amount of palatable succulent feed at the time when it is often needed to prevent a serious shrinkage in yield of milk. In a good season Sudan-grass pasture should furnish pasturage for about a cow per acre from July for 2 to 3 months.

With Sudan grass of the ordinary variety there is much less danger of prussic acid poisoning than in the case of the sorghums. However, in sections where there is any such danger, stock should not be turned on Sudan grass until it has reached a height of 18 inches to 2 feet, as it then has much less prussic acid.[54]

Short, dark green plants are especially apt to be dangerous, and the second growth usually is higher in the poison than the first growth. Frosted Sudan grass is not more poisonous than before frost, but the new growth afterwards may be high in prussic acid. The crop is higher in prussic acid in regions that are both hot and dry than in moist or cooler climates. Sudan grass rarely has any injurious effect in the southern humid regions or in the northeastern states.

Rotational grazing of Sudan grass is advisable, except in regions where there is no danger of prussic acid poisoning. Each time, the stock should not be turned in until the plants have grown up to a safe height.



SUDAN GRASS FURNISHES EXCELLENT MIDSUMMER PASTURE

Sudan grass furnishes a large yield of palatable pasturage at the time when there is en but little forage on permanent pastures.

Alfalfa, rape, Ladino clover, or red clover is much better than Sudan grass for swine pasture, where these crops thrive.[55] They not only provide more nutritious pasture but also supply forage over a much longer season. However, Sudan grass makes a useful swine pasture where the climate is too dry or otherwise unsuited to such crops. It is therefore especially adapted to the drier portions of the Great Plains, often providing more pasture than alfalfa.[56] Sudan grass is a better pasture crop for pigs over 50 to 75 lbs. in weight than for very young pigs. However, even for young pigs it is better than no pasture at

all. Since Sudan grass is rather low in protein, pigs will not make good gains on it unless fed an efficient protein supplement with their grain.

Sudan grass hay compares favorably with hay from the other grasses in feeding value, but is of considerably lower value than that from alfalfa or clover.[57] It is slightly laxative in nature. Sudan grass hay is satisfactory as the only roughage for horses and mules. For dairy and beef cattle, and especially for sheep, it gives much better results when fed with some legume hay or with silage, than as the only roughage. It has given poor results as the only roughage for fattening lambs, even when chopped and fed with a protein supplement.[58]

Sudan grass is rather difficult to cure into hay, except in the drier regions, for the large stems dry out slowly. It makes the best hay from the time it is heading out until early bloom, but the hay is satisfactory even if the crop is not cut until the seeds are in the dough stage. If Sudan grass is cut early, two cuttings can often be secured, even in the northern states. In the South, it yields 2 or 3 cuttings of hay. The content of prussic acid may not be greatly reduced when the crop is made into hay. It should therefore not be harvested for hay until it has reached a safe stage of growth.

In humid districts mixtures of Sudan grass and either soybeans or cowpeas are often grown, especially for hay. The combination usually yields more than the legume alone, and the hay is more nutritious than Sudan grass hay.

Sudan grass is a good late summer soiling crop. It also makes satisfactory silage, though a crop like Atlas sorghum is superior for silage.[59] In an Illinois trial Sudan grass-soybean silage was not quite equal to corn silage for dairy cows.[60]

Dehydrated Sudan grass meal, made from immature plants harvested at a height of 12 to 24 inches, was satisfactory when used as a vitamin supplement instead of alfalfa meal in Nebraska trials with pigs and in tests with laying hens and chicks.[61] In the experiments with pigs field-cured hay made from similar forage was also tried, but was not so good as the dehydrated product.

588. Bahia grass.—Bahia grass (*Paspalum notatum*), the most common native grass in some of the South American countries, is hardy throughout Florida and along the Gulf Coast. It will grow on drier soils than most other southern pasture grasses, because of its deep root system, and will also thrive on low-lying land. The common type of Bahia grass furnishes little feed in winter, and the seed often germinates poorly.

Pensacola Bahia grass makes more winter growth, thrives farther north, and can easily be established by seeding. The Argentine variety is nearly as frost resistant as Pensacola and is higher yielding. At times it is badly affected with ergot.[62]

589. Bent grasses.—Colonial bent grass, or Rhode Island bent grass (*Agrostis tenuis*), is a common pasture grass in New England and eastern New York, and is found southward to Virginia and westward to the Pacific slope. It thrives on soils too low in lime or too poor in fertility for bluegrass. Like bluegrass, it is a pasture grass, rather than a hay grass. Other species of bent grass are used for lawns and putting greens.

590. Bluestems.—The bluestems (*Andropogon* spp.) are among the most important native grasses of the Great Plains and form a large part of the prairie hay on the Kansas City market.[63] The composition and value of prairie hay and pasture have been discussed previously in this chapter. (577–581)

Both big bluestem and little bluestem, native species, are used to some extent for reseeding range land. Turkestan bluestem or yellow beardgrass, an Asiatic species, is well adapted for reseeding range land in the southern part of the Great Plains.[64] A variety of it is called King Ranch bluestem. Caucasian bluestem is more winter hardy and also more palatable to stock than Turkestan.

591. Buffalo grass.—Buffalo grass (*Buchloe dactyloides*) is a native fine-leaved, sod-forming grass which is the chief species on large areas of the short-grass region of the central part of the Great Plains.[65] It is resistant to drouth, and is well liked by stock. It withstands heavy grazing better than other native grasses there.[66]

592. Buffelgrass.—Buffelgrass (*Pennisetum ciliare*) is a fine-stemmed, deep-rooted perennial grass, recently introduced from Africa, which has proven extremely resistant to drouth on southern Texas ranges. It has

stayed green when even the native grasses dried up.

593. Canada bluegrass.—Canada bluegrass (*Poa compressa*) will grow on thin or poor soil where Kentucky bluegrass fails. It withstands close grazing, stays green during the summer, and makes good pasture, though less leafy and productive than Kentucky bluegrass. It is important on the poorer soils in the northeastern states and in eastern Canada.

594. Carpet grass.—Carpet grass (*Axonopus affinis*) is a perennial, creeping grass that is important as a pasture grass for the southern half of the cotton belt, being especially useful on moist, sandy lowlands. It endures close grazing well and will grow on poorer soils than Bermuda grass, but it is much less productive and nutritious than certain of the recently introduced grasses, such as Dallis grass, Coastal Bermuda grass, or Pangola grass. Though carpet grass forms a dense turf, every effort should be made to keep legumes in it, for such mixed pasture is far better.

595. Dallis grass.—Dallis grass (*Paspalum dilatatum*) is one of the most valuable pasture grasses in the cotton belt, because of its hardiness, the long growing season, and the high yield of palatable and nutritious forage. It is a perennial bunch grass, growing 2 to 4 feet tall, and is especially suited for growing with a legume. Dallis grass has a tendency to lodge and therefore is better for pasture than for hay. It requires a fertile, moist soil, but at the same time is more drouth resistant than Bermuda grass and furnishes pasture over a longer season. It is sometimes difficult to establish because of poor germination of the seed.

Dallis grass is sometimes badly affected with ergot in the seed stage. To avoid possible injury to stock, the grass should be grazed so heavily that it does not head out, or the pasture should be clipped.

596. Fescues.—During recent years two varieties of *tall fescue* (*Festuca arundinacea*) have become important for pasture in certain areas of the United States. These varieties, Alta fescue and Kentucky 31 fescue, are very similar and seem to be adapted to the same conditions.

These tall-growing fescues are long-lived perennials that produce a large yield of forage. They grow best on rich, moist soils and are tolerant of alkaline and saline salts.

Unfortunately, in many areas of our country they are so unpalatable to stock that they have given poorer results than other grasses, even when grown in combination with legumes and when the pasture has been properly managed. The palatability is particularly low if the fescue is allowed to grow up tall. The pasture should therefore be so managed that the fescue does not head out.

Because of the wide difference in the results secured in different parts of the United States, there has probably been more difference of opinion about the usefulness of Alta fescue and Kentucky 31 fescue for pasture than in the case of any other grass. In some experiments stock grazed on mixtures containing tall fescue would eat everything else before they would touch the fescue. In other experiments satisfactory results have been secured with these grasses. Because of the wide difference in the value of Alta fescue and Kentucky 31 fescue for different areas, one should consult his agricultural college or experiment station for advice, before including either in a pasture mixture.

In most of the northern states and in some other places, these fescues have given poor results in comparison with bromegrass, orchard grass, timothy, or bluegrass, because of low palatability.[67] On the other hand, the results have been satisfactory in certain areas of the southeastern states, in some sections of western Washington and Oregon and of northwestern California, and in some other places.[68]

Meadow fescue (*Festuca elatior*) is a tufted long-lived perennial grass which is adapted to wet soils in the northern states. It is grown chiefly in eastern Kansas and western Missouri. It is best as a pasture grass, starting growth early in the season and continuing till late in the fall. As the seed is high-priced, it is usually sown in mixture with other grasses for permanent pastures. Sheep fescue, red fescue, and Chewings fescue are other varieties of fescue sometimes used for pasture.

597. Grama grasses.—The grama grasses (*Bouteloua* spp.) are among the most important native grasses of the western ranges. They are warm-season perennial grasses which are resistant to drouth and grazing and are very palatable to stock. Blue grama is a low, sod-forming grass widely distributed from Arizona to the Dakotas. Black grama is even more drouth resistant and is important on semidesert southwestern grasslands. Side-oats grama is a taller-growing grass which requires more moisture.

598. Guinea grass.—Guinea grass (*Panicum maximum*), the most widely distributed tropical grass, is adapted in this coun-

try only to a narrow strip from Florida to southern California. In the Tropics Guinea grass is used chiefly for pasture, but also it is often fed as a green soiling crop. Guinea grass is a high-yielding, coarse perennial grass which thrives on well-drained soils. It is palatable to stock before it grows up and becomes tough.

In our Gulf Coast region 4 to 6 cuttings a season can be made for a soiling crop. In Hawaii Guinea grass yielded 54 tons of green forage per acre annually, containing 26 per cent dry matter.[69] It was about equal to Napier grass as a soiling crop for dairy cows. In southern Texas on irrigated land it yielded 15 tons of hay per acre a year in 8 cuttings.[70]

599. Harding grass.—Harding grass (*Phalaris tuberosa*, var. *stenoptera*), a relative of reed canary grass, is a very vigorous, long-lived, drouth-resistant, coarse bunch grass which is grown especially in southern California, both under irrigation and on dry land. In California it provides good pasture from October to May, a much longer period than the native range.[71] Like reed canary grass it is not palatable to stock when it grows up tall. In South Australia poisoning of stock sometimes occurs on pasture of this grass.[72]

600. Jaragua grass.—Brazilian jaragua grass (*Hyparrhenia rufa*) is a rather coarse, high-yielding tropical grass which has become important for pasture in certain tropical and subtropical regions. It thrives on well-drained, fertile land and is well grazed by stock if managed so that it does not become tall and unpalatable.

601. Johnson grass.—Johnson grass (*Sorghum halepense*) is a perennial southern grass which is a close relative of the sorghums and of Sudan grass. It is the worst weed of the cotton planter, and yet it is the best meadow grass for some sections of the South. Its vigorous creeping rootstocks make it very difficult to eradicate when once established, and therefore it should never be sown on clean fields.

If cut not later than early bloom, it produces high yields of good hay, and in some of the more fertile areas of the South much Johnson grass hay is produced for the market. Though early cutting reduces the yield somewhat, the feeding value of the hay is enough higher to more than offset the lower yield.[73]

To keep a Johnson grass meadow productive, it is usually necessary to plow and harrow or disc the land about every 3 years. This drastic treatment merely invigorates the Johnson grass. Sometimes an adapted legume is seeded in the Johnson grass to increase the value and to add nitrogen.

Too close continuous grazing reduces the vigor of Johnson grass. Cut at the hay stage, it makes fair to good silage.[74]

602. Love grasses.—Weeping love grass, or African love grass, (*Eragrostis curvula*) and certain other love grasses recently introduced into this country are excellent for controlling water or wind erosion in some sections of the western states. Weeping lovegrass becomes tough and unpalatable when maturity approaches, but is eaten fairly well at early stages of growth. It should generally be seeded only on poor, eroded land where better grasses will not grow or on heavily used feeding areas near the farmstead buildings. Here its tough sod will stand such use.

603. Millets.—The millets are rapid-growing, hot-weather annuals of several kinds and varieties. Of these, the *foxtail millets* (*Setaria Italica*, spp.) are the type grown most commonly for forage in the United States. In this group are common millet, Hungarian millet, and the later-maturing German millet.

In the humid sections the millets are used chiefly as catch or emergency crops, for they may be seeded late and still make a crop of hay. If sown early enough, Sudan grass produces a larger yield of more desirable forage, but the foxtail millets will do better on rather poor land. Soybeans and oats-and-peas also make hay of much greater feeding value. The foxtail millets are especially useful as hay crops on dry-land farms in the northern plains regions.

Millet should be seeded thickly for hay and should be cut just after blooming, or even before this stage. The hay is usually less palatable and inferior in feeding value to timothy hay or even well-cured corn or sorghum fodder.[75] In experiments with fattening lambs, millet hay has not given good results as the only roughage. Millet hay may sometimes cause scouring of stock.

Millet hay is satisfactory for horses if cut early and if fed as only one-third to one-half the roughage. When fed as the only roughage to horses for a long time, millet hay has produced serious lameness and swelling of the joints.[76] This was perhaps due to a considerable amount of millet seed in the hay, as these are said to have a harmful effect on the kidneys.

Japanese millet (*Echinochloa crusgalli*,

var. *frumentacea*), a cultivated, rank-growing variety of common barnyard grass, will grow better in cool regions and on wetter soils than the foxtail millets or Sudan grass. It is taller and coarser than the foxtail millets and may be used as a soiling crop, as hay, or as silage. Japanese millet hay does not apparently have the injurious effect on horses that foxtail-millet hay sometimes does.

Pearl millet (*Pennisetum glaucum*), also called cat-tail millet, is the most widely used summer temporary pasture crop in the southeastern states. Especially in the Coastal Plain area and in Florida, it produces more forage than Sudan grass and is more resistant to disease.[77]

604. Molasses grass.—Molasses grass (*Melinis minutiflora*) is a drouth-resistant perennial pasture grass important in the tropics. It will provide good pasture in areas too dry for Guinea grass. It gets its name from the somewhat sticky leaves.

605. Napier grass, or elephant grass; Merker grass.—Napier grass, or elephant grass (*Pennisetum purpureum*), is a tall, perennial tropical grass which grows 6 to 12 feet high or more in clumps of many stalks about an inch in diameter. It requires rich soil. Napier grass is an important forage crop in Florida and other warm districts of the southern states, because of the heavy yields of palatable forage. Napier grass is usually propagated by means of root or stem cuttings. One should be sure to use a disease-resistant strain.

In the tropics Napier grass is used chiefly as a soiling crop. It may be cut every 3 or 4 weeks during the growing season, but larger annual yields are secured when it is allowed to grow up for about 10 weeks.[78] When it is more mature than this, the digestibility is considerably decreased, and the feeding value is lowered. Under irrigation in Hawaii, Napier grass yielded 71 tons of soiling crop a year, containing 21 per cent dry matter.[69]

Napier grass will not stand close continuous grazing, but under rotational grazing, with periods of 20 to 30 days between grazings, it furnishes excellent pasture over a long season. It makes satisfactory silage if molasses is added and the chopped forage is well packed.

Merker grass, a shorter, more leafy variety of Napier grass, resistant to leaf spot, is widely grown in Puerto Rico.[79]

606. Natal grass.—Natal grass (*Rhynchelytrum rosea*), an annual grass well adapted to poor sandy soils in the Gulf Coast section, volunteers from year to year in many sections. It comes after early crops, and produces late summer and fall grazing or hay.

607. Oat-grass.—Tall oat-grass (*Arrhenatherum elatius*), or tall meadow oat-grass, is one of the common grasses of continental Europe, but it has never become important in this country, largely because of the high cost of the seed, which shatters badly. A non-shattering variety has been developed recently, which should make the seed more plentiful. Oat-grass is adapted to about the same conditions as orchard grass, but will not endure shade. It is usually grown in mixtures with legumes and other grasses for pasture or hay.[80]

608. Pangola grass.—Pangola grass (*Digitaria decumbens*) is a creeping perennial type of crabgrass which is adapted to fertile, well-drained soils in Florida and along the Gulf Coast westward.[81] It is chiefly used for pasture, but makes satisfactory hay if cut early. Pangola grass-white clover pasture was excellent for dairy cattle in Florida tests.[82] Because Pangola grass seeds very sparsely, it is established with runners, plants, or sprigs of green stems.

609. Para grass.—Para grass (*Panicum purpurascens*) is a perennial tropical grass with long creeping stems, which is widely grown in the Tropics. It is adapted to rich, moist soils, will grow well on land too wet for other crops, and will endure flooding for several weeks. Para grass should be grazed rotationally. If managed so that it does not become tall and woody, it is well liked by stock. It is often used as a soiling crop and makes coarse, but good hay if cut at an early stage.

Para grass is propagated by means of cuttings of the runners or pieces of green stems. In the United States it is adapted only to extreme southern areas.

610. Quack grass.—Quack grass (*Agropyron repens*), also called witch or couch grass, is one of the most widely distributed and destructive weeds of the North Temperate Zone. Though quack grass is known chiefly for its bad habits as a weed, when cut in early bloom it makes hay that is said to be equal to timothy, and it furnishes satisfactory pasture. It often forms a considerable part of the "timothy" hay on the market, especially in New England. In permanent pastures it tends to become root bound in 3 to 4 years and often nearly disappears. On account of the great difficulty of eradicating quack grass, it should never be purposely introduced on clean land.

611. Reed canary grass.—Reed canary grass (*Phalaris arundinacea*) is a tall perennial grass with coarse stems and broad leaves which thrives in the northern states on land too wet for other cultivated grasses. It will even grow on land subject to overflow for periods that would kill other grasses. Surprisingly, it stands drouth well on fertile soil. Reed canary grass is high-yielding and grows over a long season, starting early in the spring. It is a good pasture crop if the grass is not allowed to grow above a foot in height.[82] However, it is less palatable than most other pasture plants, and stock should therefore not have other pasture available when grazing reed canary grass. The pasture is better for cattle or horses than for sheep or swine. It should preferably be pastured rotationally, as it will not stand close, continuous grazing.

If cut when beginning to head out, it makes satisfactory hay and may also be used for silage, if a preservative is added. In Wisconsin tests with fattening cattle reed canary grass for silage was worth only one-half as much per ton as corn for silage, considering the feeding value of the silage and also the cost of the preservative for the reed-canary-grass silage.[83]

612. Rescue grass.—Rescue grass (*Bromus catharticus*) furnishes good winter pasture on rich soil in the southern states. It may also be cut for hay. Rescue grass is a short-lived perennial which usually behaves as a winter annual in the South and often volunteers on suitable land after being once seeded.

613. Rhodes grass.—Rhodes grass (*Chloris gayana*), a native of South Africa, is adapted as a perennial only to Florida and a narrow strip in this country along the Gulf Coast to southern Texas and westward to southern California. With irrigation, it has succeeded on soil too alkaline for other crops. It has also given good results in some areas of southern Texas, because it is drouth resistant. It produces good hay, and in central and southern Florida as many as 6 or 7 cuttings may be made in a single season. In tropical countries it is said to be the best hay grass. In Hawaii it was much less productive and less palatable than Napier grass as a soiling crop for dairy cows.[69]

614. Ryegrasses.—Perennial ryegrass (*Lolium perenne*) is a short-lived perennial which is of great importance as a pasture grass in Europe, but it is not grown extensively in this country. Italian ryegrass (*Lolium multiflorum*) generally behaves as an annual, and "domestic ryegrass" in this country is usually a mixture of both varieties and hybrids of them. The ryegrasses are grown principally in the Pacific Coast states and in the southern humid states, and have a wide range of soil adaptability. In the South ryegrass is used principally for winter pasture, usually in combination with crimson or other clover or with a small grain. It makes fine-stemmed, palatable hay when cut at the proper stage.

In a South Carolina experiment ryegrass-crimson clover furnished dairy cattle pasture for an average of 167 days, and produced an average of 3,000 lbs. total digestible nutrients per acre, equivalent to 3 tons of first-rate hay.[84]

615. St. Augustine grass.—St. Augustine grass (*Stenotaphrum secundatum*) is a creeping perennial grass well adapted to muck land in southern Florida. It is commonly used for lawns there and is also a high-yielding pasture grass. As it does not produce seed, it is established by planting pieces of the runners.

At the Everglades Station in Florida St. Augustine grass, grazed by beef cattle, has produced 690 to 780 lbs. of gain per acre and has carried more than 2 animals per acre.[85]

616. Sugar cane; Japanese cane; sugar cane bagasse.—In tropical and semi-tropical regions where sugar cane (*Saccharum officinarum*) thrives, it often produces a larger yield of green forage for cattle than other crops. The forage may be fed as a soiling crop, it may be ensiled, or it may be stored in the fall for several months in large round shocks of about 1 ton each. To avoid waste, the forage should be chopped before feeding. Sugar cane silage or chopped sugar cane which had been stored in shocks made very satisfactory roughage for wintering beef cows in Florida and Georgia tests.[86]

The tops and leaves of sugar cane, removed on harvesting the cane for sugar, also make fair forage for livestock. The amount of leaves and tops ranges from 4 to 8 tons per acre. "Strip cane," consisting chiefly of the leaves and leaf sheaths removed from the stalks at a sugar mill, was fairly satisfactory in a Hawaii test as the roughage for dairy cows when fed green or when ensiled, though inferior to Napier grass.[69]

Japanese cane, a slender-stemmed variety of the common sugar cane, is sometimes grown for forage. In Florida it furnishes good pasture for cattle and hogs from November to March, but is killed by grazing after growth starts in the spring.

Sugar cane bagasse, left at the sugar factories after as much as possible of the juice has been pressed out of the crushed stalks, is extensively used as fuel in the factories. Sometimes the bagasse is dried and the more fibrous parts are used in the manufacture of insulating board or paper. The smaller and more pithy fragments screened out are called *sugar cane pulp* or *pith.* This or the entire ground dried bagasse may be mixed with cane molasses, with or without other feeds in addition, for feeding to horses, mules, or cattle.

In a Hawaiian trial results were not satisfactory when 10 or 20 per cent of sugar cane pith was included in a concentrate mixture for dairy cows, or when 4.5 to 9.0 per cent was added to a ration for chicks or growing cockerels.[87] In a Louisiana trial with beef cattle being wintered, ground sugar cane bagasse was decidedly inferior to ground grass hay, rice straw, or cottonseed hulls, when the roughages were mixed with molasses, cottonseed meal, and minerals.[88]

617. Teosinte.—Teosinte (*Euchlaena mexicana*), a relative of Indian corn, requires a rich, moist soil and is too tropical to have value north of the southern portion of the Gulf states. Teosinte has never become important in the United States, because on moderately fertile soils it yields less than sorghum, and on rich land less than Japanese cane.

618. Wheatgrasses.—*Crested wheatgrass* (*Agropyron desertorum*) is a tall, drouth-resistant, winter-hardy, and long-lived bunch grass, especially well adapted to the northern Plains States and the drier parts of the northwestern states.[89] In these regions it is one of the best grasses for reseeding depleted range land or abandoned crop land. *Fairway crested wheatgrass* (*Agropyron cristatum*), finer-stemmed and more leafy, is used less in the United States, but is popular in western Canada.

Crested wheatgrass furnishes earlier spring and later fall pasture than the native range, and therefore supplements it admirably. It can be used for early grazing in the spring and if the stock is then transferred to native pasture, the wheat grass will grow up for a hay crop. If the moisture supply is sufficient, it will again furnish pasture in the fall. Crested wheatgrass should be cut for hay when it is heading out, or at least by blooming time, for the feeding value and palatability fall rapidly later. Early-cut crested wheatgrass hay is superior to the usual native hay in value.

Slender wheatgrass (*Agropyron trachycaulum*), a short-lived perennial bunch grass which requires somewhat more moisture than does crested wheatgrass, is prevalent in range pastures of the northern Great Plains and the Rocky Mountain region. It starts growth early in the spring and furnishes palatable feed. As it is short-lived, for reseeding it is used with grasses that require a longer time to become well established.

Western wheatgrass (*Agropyron smithii*) is a sod-forming, long-lived grass that forms a large part of the native pastures in the northern Plains States and westward.[90] Resistant to drouth and winter-hardy, it is valuable for reseeding range pasture and for erosion control.

Intermediate wheatgrass (*Agropyron intermedium*), a sod-forming wheatgrass introduced from Russia, is adapted to the same conditions as smooth bromegrass.[91] It is easily established and produces high yields of pasturage or hay.

619. Wild-rye.—Several wild-ryes occur in the native western ranges. Russian wild-rye (*Elymus junceus*), a recently introduced grass, is a deep-rooted, long-lived bunch grass, which has survived drouths that have killed other seeded grasses. Adapted for pasture on a fairly wide range of soils in the northern and central Great Plains and westward, it starts growth early in the spring and the leaves remain green and palatable to stock in summer, when the wheatgrasses are dry and unpalatable.[92]

II. Straw and Chaff

620. Feeding value of straw.—As the small grains and other plants mature, a large part of the more valuable nutrients are transferred from the leaves and stems and stored in the ripening seed. Therefore the straw, which consists of the mature stems and leaves, without the seeds, has relatively little protein, starch, or fat, while the content of fiber and lignin is high. Straw is also low in calcium and phosphorus and in most vitamins, especially in vitamin A value. Probably it generally has considerable vitamin D.

Straw is very much lower in nutritive value than is hay made from the same plants before they have matured. Also, straw is much less palatable than good hay. Because of its high content of fiber and especially of lignin, straw supplies considerably less total digestible

nutrients than good hay, and there is a far greater difference in the amount of net energy.

Straw from the small grains furnishes less than 1 per cent of digestible protein. Therefore this lack of protein must be borne in mind in feeding straw.

Because of its low nutritive value, straw is most useful as part of the ration for animals not being fed for high production. Properly supplemented, it can form a considerable proportion of the feed for wintering beef cows, stocker cattle, or idle horses and mules. It is much less useful for dairy cows, for fattening cattle or lambs, or for calves. Straw is especially unsuited to form a large part of the ration for sheep.

If straw from a combined field has lain in the windrow for several days and become weathered and discolored, the feeding value is poor.

In Europe and Canada pulped roots and meal are sometimes mixed with cut or chaffed straw, and the moist mass allowed to soften. It is then readily consumed by cattle and sheep.

Oat straw with its soft, pliable stems is the most nutritious, followed by *barley straw.* Sometimes barley straw from the varieties with barbed beards may make the mouths of stock sore. *Wheat straw,* being coarse and stiff, is not so readily eaten, and *rye straw,* which is harsh and woody, had better be used for bedding instead of being fed. *Small grain chaff* is somewhat lower in fiber and higher in protein than straw and is a little higher in value, if not loaded with dust, rust, and mold. *Rice straw,* if well cured, may be fed in the same manner as straw from the other cereals.[93]

621. Cereal straw for dairy cattle.—If plenty of better roughage is available, it is best to fill good cows up with more nutritious feed than straw. When there is a shortage of hay or other good roughage but plenty of straw, the straw may be fed once a day in place of one of the feedings of hay. To induce the cows to clean up more straw than they would otherwise eat, it may be sprinkled with diluted molasses. When good straw is used for bedding, some dairymen place the straw in the manger first and allow the cows to pick it over and eat what they will, before putting it under them for bedding.

Oat straw can be used satisfactorily, along with better roughage, in wintering well-grown dairy heifers, if plenty of protein supplement is provided. For example, in a Wisconsin trial dairy heifers made nearly as good gains on oat straw, corn silage, and 3 lbs. of a protein-rich concentrate mixture as others fed alfalfa hay, corn silage, and only 2.5 lbs. of a concentrate mixture consisting chiefly of ground corn.[94]

622. Cereal straw for beef cattle.—Straw from the small grains is satisfactory as the chief feed or even as the only roughage for wintering beef breeding cows or young cattle over a year of age, if it is properly supplemented. On the other hand, straw is too low in nutrients to form any considerable part of the ration for fattening cattle.

In the wheat-growing districts of the West, beef cows are frequently wintered on straw as the only roughage. Montana and Oregon trials show that cows in medium to good condition in the fall can be wintered satisfactorily on 12 to 20 lbs. of straw daily plus 1 lb. of cottonseed cake or meal or other protein supplement, or on straw and 4 to 5 lbs. of alfalfa or other legume hay.[95] It is very important to feed about 1 lb. per head daily of a high-protein supplement and also to supply a calcium supplement when cows are wintered on straw as the only roughage, or when fed straw with other non-legume roughage. Unless the cows have had good green pasture in the fall and consequently have a store of vitamin A in their bodies, alfalfa meal or another vitamin A supplement should be fed.

If beef cows are in good condition in the fall and the winter is mild and not too long, they can even be carried through the winter on straw alone. However, they will then lose 50 to 200 lbs. per head and may not be thrifty enough in the spring to provide sufficient milk for their calves. Such an inadequate ra-

tion should therefore be used only in emergencies.

If there is a shortage of better roughage, straw can replace part of the hay or silage usually fed fattening cattle. In such cases care must be taken that the other feeds supply sufficient protein, calcium, phosphorus, and vitamin A value. Provided the ration is properly supplemented with protein and also with calcium if needed, cattle that are full-fed on grain with a liberal amount of silage or wet beet pulp may make nearly as rapid gains with straw for the dry roughage as when fed legume hay.[96] The actual value of the straw per ton will, of course, be much lower than that of the hay, because of the larger amount of protein supplement needed with the straw.

Fair gains can even be produced on cattle a year old or more with straw as the only roughage, if a liberal amount of grain is fed and protein and calcium supplements are provided.[97]

Straw is not well suited for use as part of the roughage for fattening calves or even for wintering calves to be fattened later.[98]

623. Cereal straw for sheep.—Straw should not be fed as the only roughage to sheep, as it is too low in nutrients, especially protein, calcium, and vitamins. Moreover, it is constipating. If hay is scarce or high in price, a limited amount of straw can be used along with legume hay and silage for breeding sheep or fattening lambs.

Straw is unsatisfactory as the chief roughage for wintering breeding ewes, even when fed with a small amount of silage and plenty of protein supplement and minerals. Straw also gives very poor results as the only dry roughage for fattening lambs.[99] Feeding a mixture of half chopped barley straw and half chopped alfalfa hay with barley grain to fattening lambs was much less profitable in a California test than a ration of alfalfa hay and barley, without the straw.[100]

When sheep are to be fed such unpalatable roughage as straw, along with good legume hay, it is best to feed the straw in the morning and the better-liked hay for the evening meal.

624. Cereal straw for horses and mules.—Little or no straw should be fed to hard-worked horses or mules, for it is too poor in digestible nutrients and net energy. On the other hand, animals that are idle or at light work may be wintered largely on bright straw, instead of more expensive hay.[101] This will greatly reduce the cost. However, work stock should not be wintered on straw or stover only, for they are too low in protein, in calcium and phosphorus, and even in digestible nutrients to be the only feed, even for idle horses.

In many districts of Europe horses are fed cut straw mixed with their concentrate allowance, small amounts being thus utilized even for horses that are at hard work.

625. Straw from other plants.—When timothy, red top, or other grasses are raised for seed, the threshed *grass straw* can often be used for feeding in the same manner as cereal straw. When fed as the only roughage, wheatgrass straw and giant bluegrass straw were much less palatable than alfalfa hay to fattening lambs in a Washington test.[102]

Flax straw is about equal to oat straw, when of good quality. South Dakota experiments show that it can be used satisfactorily as the only roughage for wintering beef breeding cows or yearling steers.[103] Flax straw that has considerable green, immature flaxseed must be fed with great caution, as it may contain poisonous amounts of prussic acid.[104] Volunteer flax which sometimes springs up in the fall is very unsafe for pasturing.

Buckwheat straw is of low value and may cause digestive disturbances if fed in large amounts.

626. Straw pulp.—During serious shortages of grain and other concentrates for stock feeding, methods have been used in Europe to increase the digestibility of straw by treatment with a dilute solution of caustic soda (sodium hydroxide). In the older process, developed in Germany, the straw was digested at a high temperature under pressure. In a method tested in England during the

recent World War, straw was digested for 12 to 22 hours with a cold 1.5 per cent solution of caustic soda in an open tank. After digestion, it is necessary to wash out the caustic soda thoroughly from the treated straw pulp with running water, or by repeated washings.

Through the action of the caustic soda, some of the fiber and other resistant carbohydrates in the straw are partially hydrolyzed, or digested. Farm animals can therefore digest the straw pulp much more completely than the untreated straw. Such treated straw was found to have as high a starch value, or net-energy value, as good hay.[105]

In English feeding experiments with straw pulp the results differed rather widely, but in most tests it had a considerably higher value than untreated straw. Because straw is very bulky, considering the feeding value, so much labor was required in treating straw that the method was not used to any considerable extent in England. In certain large dairies in Sweden, larger-scale, semi-automatic equipment was developed which made such a method of practical value in time of feed shortage.[106]

QUESTIONS

1. Why should a mixture of grasses and legumes ordinarily be used for permanent pasture or meadows?
2. Compare the composition and nutritive value of grasses at various stages of growth.
3. Discuss the use and value of grass hay and mixed hay for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules.
4. How can grass hay be made that is satisfactory for dairy cows?
5. Why is timothy the great hay grass of the northern United States, and in what respects is it inferior to legumes? When should it be cut for hay?
6. What are the advantages of seeding a mixture of timothy and clover or timothy and alfalfa in comparison with seeding timothy alone for hay?
7. Why does Kentucky bluegrass rank first as a pasture grass in most of the northern half of the United States?
8. Under what conditions is red top chiefly grown?
9. Why has bromegrass attracted much attention recently in the northern and central states?
10. What are the characteristics and value of orchard grass?
11. Discuss the importance and use of Bermuda grass.
12. What is the composition and relative value of good prairie hay; of marsh hay?
13. If prairie hay is important in your district, discuss its use and value for: (a) Dairy cows; (b) beef cattle; (c) sheep; (d) horses and mules.
14. Of what importance are the small grains for forage in your district; in other sections of the United States?
15. What are the characteristics of Sudan grass? Discuss its value for hay; for pasture.
16. State the characteristics and value of 4 other grasses which are important in your district.
17. Discuss the composition of straw, and state how it may be best used in stock feeding.

REFERENCES

1. Aikman et al., Iowa Rpt. 1947.
2. Holdaway et al., Va. Tech. Bul. 45; Holdaway, Ellett, Eheart, and Pratt, Va. Tech. Bul. 65.
3. Fraser and Hayden, Ill. Bul. 146; McCandlish, Iowa Bul. 212.
4. Salisbury and Morrison, N.Y. (Cornell) Bul. 694.
5. Musbach, Wis., information to the author; Loosli, Krukovsky, Lofgreen, and Musgrave, N.Y., Jour. Dairy Sci., 33, 1950, pp. 228–242.
6. Meigs and Converse, U.S.D.A., Jour. Dairy Sci., 15, 1932, pp. 171–183; 16, 1933, pp. 317–328; Converse, Wiseman, and Meigs, U.S.D.A., Amer. Soc. Anim. Prod., Proc. 1934; see also: Bowling and Van Landingham, West Va. Bul. 290.
7. Ritzman and Benedict, N.H. Bul. 270.
8. Blizzard, Okla. Rpt. 1930–32; Blizzard and Hawkins, Okla., Rpt. 1932–34.
9. McCampbell, Kan., Amer. Soc. Anim. Prod., Proc. 1932; Anderson et al., Kan. Cirs. 130, 143, 151.
10. Keith, Stark, and Hickman, Id., Jour. Anim. Sci., 9, 1950, pp. 491–494.
11. Bell, Thatcher, and Hunt, Ohio Bul., 516.
12. Bell, Thatcher, Hunt, and Kick, Ohio Buls. 470, 479, 516, 418, 592.
13. Ritzman and Benedict, N.H. Bul. 270; Prince, Blood, and Percival, N.H. Cir. 41; N.J. Rpt. 1944; Evans, Welton, and Salter, Ohio Bul. 603; Waters and Schweitzer, Mo. Res. Buls. 19, 20.
14. Peters, Minn. Bul. 274.
15. Trowbridge and Moffett, Mo. Buls. 285, 300; Evvard, Culbertson, Wallace, and Hammond, Iowa Bul. 253.
16. Harper, Ind. Bul. 419.
17. Swift et al., Penn., Jour. Anim. Sci., 9, 1950, pp. 363–372; 11, 1952, pp. 389–399.
18. Ky. Rpts. 1949, 1950.
19. Evvard, Iowa, mimeo. rpt.; Weaver, Mo. Bul. 247; McCarty and Grimes, Penn. Bul. 254; Jacob, Tenn. Rpt. 1934; Morrison and Bohstedt. Wis. Bul. 323.

20. Sotola, Wash., Jour. Agr. Res., 63, 1941, pp. 427–432.
21. Ill. Rpt. 1938–47; Margolf, Thornton, and Callenbach, Penn. Bul. 488.
22. Aubel, Kan. Cir. 287; Hanson, Nebr. Rpt. 59.
23. Burger and Foster, Md. Bul. 444.
24. Ky. Rpt. 1950; see also: Bell, Ohio Mimeo. Series 70.
25. Foster, Biswell, and Hostetler, N.C., Jour. Anim. Sci., 4, 1945, pp. 387–394; N.C. Rpt. 1944.
26. Kuhlman, Weaver, and Gallup, Okla. Rpts. 1930–32; 1932–34.
27. Okla. Rpt. 1940–42; see also: N.D. Bul. 365.
28. Jacobsen, Ark. Bul. 318.
29. Rouse and Willhite, Colo. Farm and Home Res., 2, 1951, No. 2; 4, 1953, No. 1; Baker, Conrad, Arthaud, and Newell, Nebr. Bul. 403; Shipley, Johnson, and Miller, Nev. Rpts. 1949, 1950; Briggs, Gallup, Moxon, Gastler, Staples, and Jordan, S.D. Bul. 405.
30. Baker, Conrad, Arthaud, and Newell, Nebr. Bul. 403; see also: Adams, Ross, Hume, and Embry, S.D. Cir. 103.
31. Richard et al., N.D. Bimo. Bul. 17, 1954, No. 1.
32. Ronning and Kuhlman, Okla. Bul. B-423; see also: Atkeson, Cave, and Riddell, Kan. Rpt. 1934–36.
33. Musgrave, Williams, Norton, and Gallup, Okla. Bul. B-443.
34. G. N. Baker, and M. L. Baker, Nebr. Rpt. 1943; Fleming, Nev. Rpt. 1944; Hays, Wyo. Rpt. 1922, Wyo. Bul. 128.
35. Blizzard, Okla. Bul. 237.
36. Pope, Humphrey, Stephens, and Heller, Okla. Misc. Pub. MP-34.
37. Briggs, Okla., Jour. Anim. Sci., 2, 1943, pp. 27–32.
38. Wilson, Johnson, and Wright, S.D. Bul. 388; Bowstead and Sackville, Alberta, Canada, Col. of Agr. Bul. 19.
39. Jordan and Peters, Minn., mimeo. rpt.; see also: Minn. Farm and Home Sci., 3, 1945, No. 1; Gramlich, Nebr., mimeo. rpt.; Willham and Polson, Okla. Rpt. 1934–36.
40. Briggs, Okla. Bul. B-252.
41. Ga. Coastal Plain Bul. 48; Fieger and Lewis, La. Bul. 388; Kuykendall and Bell, Miss. Farm Res., 14, 1951, No. 8.
42. Trout and Harwood, Mich. Quar. Bul., 27, 1944, No. 1.
43. Kyzer and Pace, S.C. Rpt. 1942.
44. Willham and Polson, Okla. Rpt. 1934–36; see also: Cox, Erhart, and Sloan, Kan. Rpts.; 1946–48, 1948–50.
45. Fairbanks and Carroll, Ill. Rpt. 1938; Mich. Spec. Bul. 348.
46. Salmon, Ala. Rpt. 1940; Martin, Ark. Buls. 321, 351; McCormick, Fla. Rpt. 1944; N.C. Rpt. 1929; Kyzer and Clyburn, S.C. Rpt. 1931; Godbey, S.C. Rpts. 1932, 1933; Hale, Texas Rpt. 1939.
47. Nordby and Gildow, Id. Exten. Bul. 89; Hunter, U.S.D.A., Farmers' Bul. 599.
48. Vestal, Ind. Rpt. 1932; Evvard, Iowa Bul. 136; Ferrin and Johnson, Minn., mimeo. rpt., Lasley, Mo. Bul. 587; Robison and Jones, Ohio Bul. 516; S.D. Rpt. 1931; see also: Southwell and Treanor, Ga. Coastal Plain Bul. 41.
49. Ariz. Rpt. 1948; Guilbert, Cal. Bul. 481; Md. Bul. A-50; Vinke and Dickson, Mont. Bul. 275.
50. Hackedorn and McCall, Wash. Bul. 302; McCall and Hackedorn, Wash. Bul. 352; McDonald and Ensminger, Wash. Bul. 439.
51. Lindgren, Ore. Exten. Bul. 639; Ore. Bul. 350.
52. Sotola, Wash., Jour. Agr. Res., 54, 1937, pp. 399–415.
53. Bradley, Eppson, and Beath, Wyo. Bul. 241.
54. Boyd, Aamodt, Bohstedt, and Truog, Wis., Jour. Amer. Soc. Agron., 30, 1938, pp. 569–582; Burcalow and Bohstedt, Wis. Cir. 298.
55. Martin, Ark. Buls. 323, 354; Evvard and Culbertson, Iowa, mimeo. rpt.; McCarty and Grimes, Penn. Buls. 254, 276; S.C. Rpt. 1926; Tenn. Rpts. 1931, 1932.
56. Aubel, Kan. Cir. 308; Mont. Rpt. 1927; Nebr. Rpt. 1924, 1926; Hale, Tex. Rpts. 1937, 1941.
57. Cunningham and Davis, Ariz. Rpt. 1921; Fort Hays Branch Station, Kan., Livestock Investigations, Rpts. 1923, 1924, 1925; McCampbell et al., Kan., Cattlemen's Round-up, 1933, 1934, 1935.
58. Miller, Cal. Rpt. 1931; Darlow, Okla. Bul. 213; Johnson and Johnson, S.D. Bul. 373.
59. Atkeson, Bechtel, Shaw, and Beck, Kan. Rpt. 1938–40.
60 Nevens and Kendall, Ill. Bul. 578
61. Hanson and Loeffel, Nebr. Rpts. 1941, 1942, 1943, 1944; Ackerson, Blish, and Mussehl, Nebr. Res. Bul. 116; Nebr. Rpt. 1940.
62. Killinger, Ritchey, Blickensderfer, and Jackson, Fla. Cir. S-31.
63. Hughes, Heath, and Metcalfe, Forages; Wheeler, Forage and Pasture Crops.
64. Harlan, Okla. Forage Crops Leaflets 7, 11; Tex. Rpt. 1949.
65. Beetle, Wyo. Bul. 293.
66. U.S.D.A. Yearbook of Agr., 1948. Grass.
67. Phillips, Del. Bul. 271; Mott, Beeson, and McVey, Ind. Rpts. 63, 64; Ky. Rpts. 1950, 1952; Seath, Lassiter, Bastin, and Elliott, Ky. Bul. 609; Bell, Ohio, Anim. Sci. Mimeo. Ser. 70; Pratt and Davis, Ohio Farm and Home Res. No. 291; R.I. Rpt. 1948, Stucky, R.I. Bul. 313; see also: Sandal, Staten, and Davis, Ark. Bul. 537; Ittner, Guilbert, and Carroll, Cal. Bul. 745; Baird, Ga. Research News, 3, 1952, No. 8; McCullough, Ga., Jour. Dairy Sci., 36, 1953, pp. 445–449; Vegors, Sell, Baird, and Stewart, Ga., Jour. Anim. Sci., 14, 1955, pp. 256–257; Tenn. Rpts. 1950, 1952; Bateman, Keller, and Packer, Utah Farm Sci., 10, 1949, No. 1; Thompson and Holdaway, Jour. Dairy Sci., 37, 1954, p. 666; Galgan, Ensminger, and Ham, Wash. Stas. Cir. 116.
68. Fla. Rpt. 1951; McKinney, Ga. Rpt. 1951; La. Rpt. 1951; Burger and Foster, Md. Bul. 444; Marlowe, Leveck, and Horn, Miss. Farm Res., 14, 1951, No. 10; Miss. Rpt. 64; Thompson, Dyer, and Guyer, Mo., Jour. Anim. Sci., 14, 1955, p. 1241; McCormick, Kidwell, and Robertson, Nev. Cir. 4; Woodhouse and Barrick, N.C. Res. and Farming, 11, 1953, Nos. 3–4; Harlan and Elder, Okla. Forage Crops Leaflet 5; King, LaMaster, and Mitchell, S.C. Agr. Res., 1, 1954, No. 2; Lindley, Ensminger, and Schneider, Wash. Stas. Cir. 111.
69. Henke, Hawaii Bul. 92.
70. Hoveland, Texas Prog. Rpt. 1675.
71. Love, Osterli, and Berry, Cal. Agr., 7, 1953, No. 12.
72. Lee and Kuchel, Australian Jour. Agr. Res., 4, 1955, pp. 88–89.
73. Miss. Rpt. 66; see also: Davis, Johnston, Rusoff, and Woodward, La. Rpt. 1952.
74. Ark. Bul. 428; Bennett et al., Miss. Farm

Res., 8, 1945, No. 11; Staten and Elwell, Okla. Bul. 281.
75. Morton, Maynard, Brandon, and Osland, Colo. Bul. 395, Colo. Press Bul. 80; Mumford, Mich. Bul. 136.
76. Hinebaugh, N.D. Bul. 26; Bell and Williams, U.S.D.A. Farmers' Bul. 1030.
77. Marshall, Sanchez, Somers, and Dix Arnold, Fla. Bul. 527; Ga. Coastal Plain Bul. 48; Ellzey, Beaubouef, and Hodgkins, La. Rpt. 1951; Roark, Miles, Lusk, and Cowsert, Miss. Farm Res., 15, 1952, No. 3; see also: Thurman, Staten, and Burdick, Ark. Farm Res., 2, 1953, No. 4; Fortmann, Carnahan, Pennington, and Washko, Penn. Progress Rpt. 25.
78. Nordfeldt, Iwanaga, Tom, and Henke, Hawaii Tech. Bul. 12; Hawaii Rpts. 1946–48, 1948–50, 1950–52.
79. Rivera-Brenes, Puerto Rico Tech. Paper 12.
80. Fuelleman, Burlison, and Kammlade, Ill. Cir. 647; Wasko, Thornton, and Higbee, Penn. Bul. 568.
81. Hodges, Jones, and Kirk, Fla. Bul. 484; Cunha, Killinger, and Baker, Fla. Rpt. 1952; Marshall, Fla., Jour. Dairy Sci., 37, 1954, p. 666.
82. Vary, Davis, and Harrison, Mich. Quar. Bul., 33, 1950, No. 1.
83. Bohstedt and Grummer, Wis. Bul. 469.
84. LaMaster, King, and Mitchell, S.C. Bul. 380.
85. Fla. Rpt. 1953.
86. Kirk and Crown. Fla. Bul. 358; Stevenson and Southwell, Ga. Coastal Plain Cir. 13.
87. Wayman, Iwanaga, Henke, and Weeth, Hawaii Cir. 43; Henke, Hawaii Rpt. 1950–52; Rosenberg, Hawaii Bul. 109.
88. Brown, Damon, Singletary, and Vernon, La., Jour. Anim. Sci., 13, 1954, pp. 1006–1007.
89. Williams and Post, Mont. Bul. 431; Mont. Rpts. 50–59; Longwell and Huber, N.D. Bimo. Bul. 4, 1942, No. 5; Thomas and Mumford, Ore. Bul. 448; Harris et al., Utah Farm and Home Sci., 11, 1950, No. 4; Short, U.S.D.A. Farmers' Bul. 1924.
90. Duitsman and Kessler, Kan. Cir. 307; McIlvain, Okla. Bul. B-319; Adams, Ross, Worzella, and Hume, S.D. Cir. 81; Johnson and Johnson, S.D. Bul. 373; Wyo. Cir. 35.
91. Esplin and Tucker, Colo. Farm and Home Res., 3, 1952, No. 1; Id. Bul. 280; Kessler, Aicher, and Meenen, Kan. Cir. 276; Lindley, Ensminger, and Schneider, Wash. Stas. Cir. 111.
92. Hervey and Johnson, Colo. Farm and Home Res., 5, 1954, No. 4; Barnes and Nelson, Wyo. Bul. 302.
93. Brown, Damon, Singletary, and Vernon, La., Jour. Anim. Sci., 13, 1954, pp. 1006–1007.
94. Morrison, Oosterhuis, and Bohstedt, Wis. Bul. 275; see also: Ore. Rpt. 1918–20.
95. Arnett, Baker, and Vinke, Mont. Bul. 187; Arnett and McChord, Mont. Bul. 211; Vinke and Dickson, Mont. Bul. 275; Ore. Rpt. 1928–30; see also: Aicher, Weber, and Kessler, Kan. Cir. 260.
96. Morton, Osland, and Tom, Colo. Press Buls. 82, 88; Tom and Connell, Colo. Farm Bul., 5, 1943, No. 5; Rusk, Ill., mimeo. rpt.; Skinner and King, Ind. Buls. 163, 167, 396, 428, 429; King, Ind. Bul. 500; see also: Duitsman and Kessler, Kan. Cir. 307.
97. Thalman, Nebr., mimeo. rpt.
98. Johnson, Rinehart, and Hickman, Id. Buls. 264, 268; Duitsman and Kessler, Kan. Cir. 322.
99. Kammlade and Mackey, Ill. Bul. 260; Skinner and Vestal, Ind. Buls. 234, 256; Skinner and King, Ind. Bul. 263; Paterson and Winchester, Kan. Cir. 96; Minn. Farm and Home Sci., 3, 1945, No. 1; Ore. Rpt. 1934–36; Ikeler, Utah Bul. 220.
100. Miller, Cal. Rpt. 1923; see also: Wyo. Rpt. 1934.
101. Trowbridge, Mo. Buls. 163, 179; see also: Norton, Mich. Bul. 254.
102. Ensminger, Warwick, and Cunha, Wash. Bul. 255.
103. Wilson, Wright, and Fenn, S.D. Cir. 3, and mimeo. rpt.
104. Ince, N.D. Bul. 106; Stevens, N.D. Bul. 265.
105. Watson, Jour. Roy. Agr. Soc., England, 101, 1941, pp. 37–43; Williamson, Jour. Agr. Sci., England, 31, 1941, pp. 488–499; Jour. Min. Agr., Great Britain, 48, 1941, pp. 85–91; 49, 1942, p. 2; Woodman, Jour. Min. Agr., Great Britain, 50, 1943, pp. 308–314; Bartlett and Blaxter, Jour. Min. Agr., Great Britain, 50, 1943, pp. 224–226; Watson, Jour. Min. Agr., Great Britain, 50, 1943, pp. 365–368; Ferguson, Jour. Agr. Sci., England, 33, 1943, pp. 174–177.
106. Jarl, Sweden, information to the author.

CHAPTER XIX

ROOTS, TUBERS, AND MISCELLANEOUS FORAGES—POISONOUS PLANTS AND POISONOUS FEEDS

I. Roots and Tubers

627. Roots unimportant for livestock in the United States.—In the United States the acreage of roots raised for feeding livestock is insignificant in comparison with that of other forage crops. On the other hand, in northern Europe extensive use of roots is made for stock feeding.

This great difference is due chiefly to the difference in the climate. Northern Europe with its cool summers is well adapted to the growing of roots but not to the raising of corn. In most parts of our country the summers are hot, and corn or the sorghums thrive, furnishing in the form of silage a palatable succulent feed which is much cheaper than roots. Also, root crops require much hand labor, and labor is cheaper in Europe than in this country.

In the United States the growing of roots for livestock is advisable only under certain very special conditions. Roots may be used as a substitute for corn silage where the summers are too cool for corn, though hay-crop silage is generally a much more economical source of nutrients. Sometimes roots are fed as a relish to animals being fitted for show or to cows on official test. Occasionally, roots are grown to supply succulent feed for poultry in winter. However, most roots do not replace alfalfa meal as a vitamin supplement, and poultrymen have therefore largely discontinued their use.

While the acreage of root crops grown for stock feeding in the United States is very small, the production of sugar beets for sugar manufacture is of importance in certain sections, particularly in Colorado and other western Mountain States. The by-products from this industry—beet tops, beet pulp, and beet molasses—are used for stock feeding. Also, cull and surplus potatoes and sweet potatoes are important by-product feeds in certain sections.

628. Composition and value of roots and tubers.—All roots and tubers are very watery and low in dry matter. Especially so are mangels, turnips, and rutabagas, which have only 9 to 11 per cent dry matter. This is less than half the percentage of dry matter in corn silage. However, the dry matter that roots and tubers do contain is of high quality, being low in fiber, highly digestible, and high in net energy per pound. Roots and tubers are therefore more like watery concentrates than like roughages. For convenience, they are grouped with green roughages in the Appendix Tables of this book.

The chief nutrients in roots and tubers are carbohydrates—largely cane sugar in beets and mangels, and starch in potatoes. Roots and tubers are low to fair in protein content, are low in calcium, and are only fair in phosphorus. Carrots and sweet potatoes are rich in carotene, but other roots and tubers have little or no vitamin A value. Roots or tubers do not supply vitamin D. They are low in riboflavin, but are quite high, on the dry basis, in niacin.

Roots and tubers are therefore decidedly different from legume hay or other legume forage, which is rich in protein, in calcium, and in carotene, and rather high in riboflavin. Also, field-cured hay from legumes or other crops is an important source of vitamin D in the winter feeding of all stock except poultry, while roots and tubers do not supply this vitamin.

Although roots cannot replace legume hay in stock feeding, they can be

used as a substitute for a considerable part of the grain customarily fed to dairy cows or to fattening cattle and lambs. This is usually not economical in the United States, but is a common practice in northern Europe. In most of the trials with dairy cows a pound of dry matter in such roots as mangels, sugar beets, or rutabagas has been equal to a pound of dry matter in grain, such as corn, wheat, or barley, or at least equal to a pound of these grains.[1]

breeding cattle and sheep in thrifty condition.

When roots are fed to stock in this country, cattle are not usually fed more than 20 to 30 lbs. per head daily, fattening lambs not more than 4 or 5 lbs. and breeding ewes 2 to 3 lbs. In Europe much greater amounts are often fed.

Roots should be chopped or sliced before feeding, when there is any danger of livestock choking on them. Any undue amount of dirt should be removed before the roots are chopped. Often the grain or concentrate mixture is sprinkled over the chopped roots. Cooking or steaming roots or tubers is a waste of labor and fuel, except that potatoes should be cooked for swine and poultry. In Europe, roots for fattening cattle are often pulped and spread in layers, alternating with layers of cut hay or straw. After being shoveled over, the mass is allowed to stand several hours before feeding, to moisten and soften the straw or hay. In this manner considerable straw may be utilized.

SUGAR BEETS IN A WESTERN IRRIGATED DISTRICT

While but relatively few acres of sugar beets are grown for stock feeding in this country, the raising of sugar beets for the beet sugar factories is an important industry in certain sections, especially in some of the irrigated districts of the West. (From U.S. Reclamation Service.)

Because such roots as mangels, rutabagas, and turnips contain less than half as much dry matter as corn silage, they are worth much less per ton for stock feeding. Experiments have shown that for dairy cows 100 lbs. of corn silage are worth more than 200 lbs. of these roots. For fattening lambs it has required, on the average, 145 lbs. of roots to replace 100 lbs. of corn silage.

In addition to the nutrients they furnish, roots and other succulent feeds have a beneficial effect upon animals and are highly esteemed for keeping

For winter feeding in the northern

states roots must be stored in well-ventilated pits or cellars, but in mild climates they may remain in the field until fed. In experiments in Ireland, mangels lost about 27 per cent of their dry matter during 5 months' storage, because of the respiration which is continuously taking place.[2]

The root crops most commonly grown for stock feeding are mangels, rutabagas, and turnips. Sometimes sugar beets, carrots, parsnips, or potatoes are raised especially for this purpose.

629. Roots vs. silage.—It costs considerably more to grow an acre of roots than to grow an acre of corn and ensile it, because root crops require more thorough preparation of the soil and far more hand labor in cultivation, harvesting, and storage. Also, experiments have shown that where corn thrives it yields much more dry matter per acre than the best root crops. As a result of the greater cost in growing roots and their lesser yield of nutrients per acre, corn silage will furnish digestible nutrients at half the cost of roots in good corn-growing sections.

Occasionally, some persons get an incorrect idea of the economy of root crops, because of the very large tonnage sometimes produced. Under very favorable conditions such root crops as mangels, sugar mangels, or rutabagas may yield 20 to 30 tons per acre or even more. This is a far greater fresh weight than is secured in corn silage, but the roots are so watery that the corn crop will yield a much larger amount of dry matter and digestible nutrients per acre.

In localities in this country where the growing season is too short or the weather too cool for corn, hay-crop silage will generally supply succulent feed at decidedly less cost than root crops.

630. Roots for dairy cattle.—Roots are an excellent feed for dairy cattle, but they are so uneconomical in this country that they are rarely fed. Roots may be a useful feed where a dairyman does not keep sufficient stock so that he can feed silage fast enough to keep it from spoiling, or if a silo is not available. Years ago roots were widely used for cows on official test, where the object may be maximum yield of milk rather than low cost of production. However, soaked beet pulp is now generally used in place of roots, because of the greater convenience. Like silage and soaked beet pulp, roots are believed to have a "cooling" effect on the digestive system, helping to prevent digestive trouble when cows are heavily fed on concentrates.

Experiments have shown that adding roots to a palatable ration containing corn silage tends to increase the yield of milk and fat slightly.[3] This is doubtless because roots are so well liked by cows that their feed consumption is greater when roots are fed. However, the increase in production is not large enough to offset the cost of the roots, with milk at usual prices.

In feeding trials with dairy cows the dry matter of corn silage has been as valuable or nearly as valuable as that in roots.[4] Since roots have much less dry matter than corn silage, they are worth correspondingly less per ton. For example, it requires about 3.0 tons of mangels, 2.5 tons of rutabagas, or 1.7 tons of sugar beets to furnish as much dry matter as in 1 ton of good corn silage. These figures therefore represent approximately the amounts of root crops it takes to equal a ton of corn silage for milk production.

When roots are fed to dairy cows as the only succulent feed in place of corn silage, the production of milk and fat will be about as high and perhaps even slightly higher than on corn silage. However, in good corn-growing sections, the production on the silage ration will be much more economical.[5] Compared with root crops, silage of the kind that can be produced in Great Britain, where corn does not thrive, has given varying results. In some trials the production has been more economical on roots than with silage made from such mixtures as oats with peas or vetch, and in other tests the silage ration has been cheaper.[6]

631. Roots for beef cattle.—Although roots are rarely fed to beef cattle in this country, they are extensively used

for this purpose in Great Britain and other northern European countries where corn does not do well. Sometimes fattening cattle are given all the chopped or sliced roots they will clean up, along with a limited amount of concentrates and hay or straw. The hay or straw is often chopped and mixed with the roots. By this means the cattle may be induced to eat considerable straw or poor hay. Because of the high water content of roots, the amounts eaten are surprisingly large. Often cattle 2 years old or over will eat 80 to 100 lbs. of roots per head daily, if fed all they will take. When cattle are fed only 40 to 60 lbs. of roots a day with a greater amount of other feeds, the gains will be as good as when the maximum amount of roots is supplied. In this system of fattening cattle much less grain is used than in our country, but good gains and carcasses of excellent quality are produced.

In Canadian trials corn silage was worth considerably more per ton than roots, because of its much greater content of digestible nutrients.[7] When only a few pounds per head daily of roots are fed to cattle as an appetizer, they may be worth as much, pound for pound, as corn silage.[8]

632. Roots for sheep.—Roots are an excellent succulent feed for sheep, but in the United States silage is usually much more economical. Because such roots as rutabagas, turnips, and mangels are far more watery than corn silage, it has taken about 145 lbs. of roots to equal 100 lbs. of corn silage in experiments with fattening lambs.[9]

Some shepherds have believed that roots are preferable to corn silage for breeding ewes. However, in 4 Wisconsin experiments the percentage of strong lambs was noticeably higher when ewes were fed corn silage as part of the roughage in a well-balanced ration, than when rutabagas replaced the silage.[10] In these trials rutabagas were worth only about two-thirds as much per ton as corn silage, not considering the better lamb crops from the ewes fed silage. Rutabagas were also less valuable than corn silage for wintering ewe lambs.

In Great Britain roots are widely fed to sheep of all classes. Sometimes fattening lambs are fed as much as 15 to 20 lbs. of rutabagas or other roots per head daily, though much smaller allowances are more common. In this country it is unusual to feed more than 4 to 5 lbs. of roots per head daily to fattening lambs, and even half this allowance, preferably chopped, will furnish enough succulence in the ration. When pregnant ewes are fed too much roots, weak lambs sometimes result, probably due to a lack of protein or minerals in the ration. The allowance of roots had therefore best be restricted to 2 or 3 lbs. per head daily, and good hay should be fed in addition.

Some believe feeding mangels or sugar beets to sheep over long periods may tend to produce calculi, or stones, in the kidneys and bladder, which are dangerous in the case of rams and wethers. The roots may not be the primary cause of the trouble, however, as calculi occur when sheep are fed no roots.[11]

633. Roots for horses.—Occasionally roots, especially carrots, are fed to horses in this country as an appetizer or an aid to digestion, where cost of keep is not considered. Hard-worked or driving horses should not be fed large allowances of roots. Some advise feeding no roots to brood mares for a few weeks before and after they foal.[12]

634. Roots for swine.—Roots were formerly esteemed by many swine raisers, especially for feeding brood sows. However, in Wisconsin experiments with brood sows and fattening pigs, when roots were added to efficient rations containing legume hay, the roots had so low a value that they were very uneconomical.[13] In no case did the addition of roots result in the sows having larger or more thrifty pigs.

In these trials alfalfa or clover hay was a much more efficient addition than roots to the rations of brood sows or fall pigs. We might expect this, since legume hay is rich in good-quality protein, in calcium, in carotene, and in vitamin D, and it also has a desirable laxative

effect. Roots are palatable, succulent, and laxative, but they are low in protein and in calcium. Moreover, roots are lacking in vitamin D, and roots, except carrots, have little or no carotene (vitamin A value).

In experiments conducted many years ago in which roots were added to inefficient, old-time rations for pigs, 448 lbs. of roots, on the average, saved 100 lbs. of concentrates.[14] However, roots have a decidedly lower value than this for swine when added to modern well-balanced rations which include some legume hay as a vitamin supplement.

635. Roots and other succulent feeds for poultry.—Some years ago it was considered nearly essential to supply succulent feeds to hens in winter to secure maximum egg production. This has been entirely changed by the efficient dry rations that have been developed through the discoveries in poultry nutrition.

When modern rations are used which provide a plentiful supply of vitamins and meet the protein and mineral requirements fully, poultry produce excellent results during the winter without fresh green feeds or other succulent feeds. The practice of growing cabbage or roots especially for poultry has therefore been largely discontinued.

When green feeds and other succulent feeds are available for poultry, there is no question but that they are excellent additions to winter rations. Therefore, such green feeds as cull or waste cabbage or other vegetables should be fully utilized. Where cabbage is raised for market, the small, unmarketable heads make a cheap feed for poultry. The cabbage heads should be suspended by a string about 18 inches from the floor, so that the birds can reach them easily. A good method of feeding mangels or sugar beets is to split them lengthwise and stick the halves on nails driven in the walls of the hen house, about 18 inches from the floor, and then let the fowls pick at them.

636. Potatoes.—In the United States other crops excel potatoes (*Solanum tuberosum*) for feed production, and therefore only cull or surplus potatoes are generally fed to stock. On the other hand, in some sections of Europe heavy-yielding varieties of large-sized potatoes are often raised for stock. (The use of dehydrated potatoes for feeding is discussed in Chapter XXIII.)

Potatoes contain about twice as much dry matter as rutabagas or carrots. However, they are more watery than many realize, for they have less dry matter and less total digestible nutrients than well-eared corn silage. They are rich in starch, on the dry basis, but are only fair in protein. They are deficient in vitamins A and D. These lacks are made good when potatoes are fed with well-cured legume hay.

Potatoes are satisfactory for feeding to dairy cows, beef cattle, sheep, horses, swine, and poultry in limited amounts as a substitute for grain or other low-protein feed. It takes about 400 to 450 lbs. of potatoes to supply as much total digestible nutrients as there are in 100 lbs. of grain, and this is approximately the value of potatoes as a substitute for grain in stock feeding. Stated in another way, 100 lbs. of potatoes are worth about 22 to 25 per cent as much as 100 lbs. of grain.

Potatoes should be cooked for swine and poultry, but this is not necessary or profitable for other stock. It has been generally recommended that potatoes should be chopped before feeding to cattle or sheep, to make them more palatable and avoid choking. However, in recent Minnesota trials fattening cattle seemed to prefer whole to sliced cull potatoes.[15] Stock should be accustomed to potatoes gradually, as they are not very palatable. Feeding too large amounts of raw potatoes may cause scours.

Unripe potatoes and especially the sprouts of stored potatoes contain small amounts of solanin, a poisonous compound. It has therefore been advised that in feeding badly-sprouted potatoes the sprouts be removed. In trials at the North Dakota Station, however, when dairy cows were fed for considerable periods on reasonable quantities of sprouted, sunburned, or decomposed potatoes, and even on potato sprouts, along with other feeds, there was no injurious effect.[16] Nevertheless, because of reports of stock being injured by excessive amounts of potatoes, it is not wise to let them have access to an unlimited amount of either good or poor-quality potatoes.

637. Value and use of potatoes for various classes of stock.—For dairy cows potatoes were a satisfactory substitute for corn silage in Idaho and North Dakota trials, be-

ing nearly equal to silage in value per ton when 24 to 40 lbs. were fed per head daily.[17] However, the potatoes were not so palatable as silage, and the cows seemed to lose their appetites for potatoes after several months. Fed in such quantities, potatoes did not affect the flavor of the milk or the odor of the milk or butter, but milk or cream exposed to an atmosphere heavy with potato odor readily took it up. Potatoes should therefore be fed immediately after milking and not before.

When a large allowance of potatoes was fed to cows in Vermont tests, the potatoes were not equal to the same weight of dry matter in corn silage, and the butter was soft.[18] If potatoes are fed in a properly-balanced ration they do not dry up cows, as is sometimes believed.

Cull potatoes have been used satisfactorily in place of corn silage for fattening beef cattle and beef breeding cows.[19] For fattening cattle cull potatoes were worth about 80 per cent as much a ton as corn silage, or twice as much per ton as rutabagas. In Minnesota trials good gains were made by yearling steers fed cull potatoes, oat straw, protein supplement, and a little grain.[20] Oat straw was better for feeding with potatoes than legume hay, as it counteracted the laxative effect.

Cull potatoes are satisfactory as part of the ration for fattening lambs or for wintering breeding ewes.[21] In 12 comparisons with fattening lambs the addition of cull potatoes to a ration of grain and legume hay, with or without a protein supplement, has usually increased slightly the gains of the lambs. In these trials one ton of potatoes was equal in feeding value, on the average, to 199 lbs. grain and other concentrates plus 447 lbs. alfalfa hay. With hay valued at half the price of grain per ton, cull potatoes would be worth 21 per cent as much per ton as grain.

Horses and mules may be fed potatoes, cooked or raw, in amounts up to 15 or 20 lbs. per head daily.

In English experiments when cooked potatoes were fed to pigs as a partial substitute for grain in well-balanced rations, it required about 410 lbs. of potatoes (weighed before cooking) to equal 100 lbs. of grain and other concentrates.[22] In South Dakota and Washington tests cooked potatoes had a slightly higher value than this when added to properly-balanced rations.[23] For the best results in swine feeding, the proportion of potatoes should not be greater than 4 lbs. of potatoes to each pound of concentrates. It is best to add salt to the water in which the potatoes are cooked, to increase the palatability. The potatoes should be cooked thoroughly, and the water in which they are cooked should be discarded, as it is not palatable. Raw potatoes generally produce poor results when fed to swine.[24]

Boiled or steamed potatoes are a satisfactory substitute for part of the grain for poultry. The cooked potatoes, after being mashed, may be mixed with an equal weight of the regular dry mash and fed as a warm, moist mash. When potatoes are added to the ration, it must be borne in mind that they are very low in protein, and that they do not supply vitamin A value. In Ohio experiments it required 410 to 467 lbs. of cooked potatoes (weighed before cooking) to replace 100 lbs. of dry mash in feeding broilers, growing pullets, and laying hens.[25]

Because of the great shortage of grain and other concentrates for livestock feeding in Europe during the recent war, potatoes were used extensively as a considerable part of the rations for poultry. The results were good when care was taken to supply sufficient vitamins and protein in the potato rations.[26]

The value and use of dried or dehydrated potatoes are discussed in a later chapter. (981)

638. Potato silage.—Experiments show that satisfactory silage can be made by running a combination of potatoes and hay or dry corn or sorghum fodder through the silage cutter.[27] It is best to add 20 to 25 lbs. of dry forage to each 100 lbs. of potatoes, but even 10 lbs. may produce satisfactory silage. The dry forage absorbs most of the excess moisture of the potatoes, and the combination goes through the proper silage fermentation. The silage is eaten readily by stock and is approximately equal to corn silage in value per ton. For dairy cows the allowance had best be limited to about 40 lbs. daily per 1,000 lbs. live weight. Silage made from raw potatoes is not satisfactory for swine or poultry.

A silo for potato silage must be very well reinforced to stand the pressure of the heavy material, and it should have drains to allow the escape of surplus juice. Stones taken up with the potatoes in harvesting may often damage the knives of the silage cutter.

Chopped raw potatoes alone do not make good silage, and satisfactory silage may not be produced when 2 to 3 per cent by weight of ground corn is added as a preservative. On the other hand, well-steamed potatoes can be successfully ensiled. This method has been used considerably in Germany, but

under usual conditions it would be much simpler and more economical to ensile potatoes with hay or other dry forage. In an experiment in Norway steamed potato silage or steamed potatoes satisfactorily replaced part of the grain for feeding bacon pigs.[28]

Potatoes can also be mixed with green corn or sorghum fodder or a green hay crop as it is ensiled. It is best to use not more than 500 lbs. of potatoes with each ton of green fodder.

639. Sweet potatoes.—Sweet potatoes (*Ipomea batatas*) are a southern root crop which is raised chiefly for human food. Recently considerable acreages have been used for starch manufacture and for the production of dried sweet potatoes for stock feeding. (The value of dried or dehydrated sweet potatoes is discussed in Chapter XXIII.) Each year several million bushels of cull or unmarketable sweet potatoes from crops grown for table stock are available for feeding in the South, and some are grown primarily for feeding livestock.

SWEET POTATOES PRODUCE A LARGE YIELD PER ACRE

In the southern states sweet potatoes yield more dry matter per acre than does corn grain. However, the cost per acre of growing sweet potatoes is considerably greater.

In this Alabama field of sweet potatoes the vines have already covered the field. (From Ware, Alabama Station.)

In the southern states sweet potatoes will produce more dry matter and a greater feeding value per acre than corn grain, but the cost is considerably higher per acre in growing sweet potatoes, because of the greater amount of labor required. The average acre yield of sweet potatoes in this country was 93.6 bushels, weighing 55 lbs. each, for the 10-year period 1945–1954. Much larger yields are secured under good conditions in the chief producing sections. In 3-year tests at 8 locations in the South the average yield was 225 bushels per acre.[29]

Sweet potatoes are high in dry matter for a root crop, averaging 31.8 per cent, and they are rich in starch, but they are extremely low in protein. They are also low in calcium and phosphorus. These lacks must be borne in mind in feeding them. Sweet potatoes are high in carotene, and the deeper-colored varieties are much richer than those lighter in color.

Chopped sweet potatoes are a good feed for dairy cows and can be used as a substitute for corn or sorghum silage, or in place of part of the grain ordinarily fed. In Louisiana trials 100 lbs. of chopped sweet potatoes equalled 250 lbs. of corn or sorghum silage.[30]

In a Tennessee test with fattening cattle 100 lbs. of chopped sweet potatoes had a somewhat greater value than 150 lbs. of silage, and in a Georgia test with fattening lambs 300 lbs. of sweet potatoes fully replaced 100 lbs. of corn grain.[31]

Sweet potatoes have been used most extensively for feeding swine, pigs often being turned in the field to harvest the crop. When pigs are grazed on sweet potatoes or are fed the harvested tubers, the best results are secured if they are fed one-third to one-half

the usual grain allowance, in addition to protein and mineral supplements. Only well-grown pigs or older hogs should be grazed on the crop, as sweet potatoes are too bulky for small pigs. Sweet potatoes produce hard pork, but pigs heavily fed on them tend to be paunchy and have a low dressing percentage.

In Louisiana tests it required 4.3 lbs. of sweet potatoes to equal 1 lb. of grain and other concentrates, when fed in dry lot; and 4.9 lbs. of the potatoes (but not including the vines eaten) to equal 1 lb. of corn when the crop was hogged-down.[32] The value was much lower when proper supplements were not provided.

Since sweet potatoes supply about one-third as much total digestible nutrients as corn, these values are somewhat lower than would be expected from the chemical composition. In a South Carolina test cooked sweet potatoes, fed with an efficient protein supplement, produced just as good gains on fattening pigs as did corn with the same supplement.[33] On the other hand, much less satisfactory results were secured from raw sweet potatoes.

Cooked sweet potatoes were used satisfactorily in a ration for laying hens in a Louisiana trial.[34]

Satisfactory silage was made in a trench silo from chopped sweet potatoes, without preservative, in a Georgia experiment.[35]

640. Sweet potato vines.—The green weight of the sweet potato vines per acre from a good crop of sweet potatoes is greater than the usual yield of corn forage, and the vines are a nutritious forage. Sometimes stock are turned on sweet potato fields to graze on the vines after the crop is harvested. However, often but little use is made of the vines because it has been necessary to harvest them by hand, since they are rooted in the soil every few inches of their length. Machines have been developed to solve this harvesting difficulty.

Sweet potato vines are hard to cure into good hay, as they are very high in water, but they make satisfactory silage without a preservative. Allowing the vines to wilt before ensiling them is probably advisable. In an Alabama test sweet-potato-vine silage was equal to corn silage for fattening cattle, and in North Carolina trials silage made from a combination of sweet potato vines and cull sweet potatoes was equal to corn silage for dairy cows.[36]

641. Mangels; fodder beets.—Mangels, or mangel wurzels (*Beta vulgaris*, var.), are very low in dry matter, having only 9.2 per cent. Yet due to the heavy yields—20 to 30 tons per acre on good soil and under favorable conditions—they produce a large amount of dry matter per acre. Because they stand well out of the ground, mangels are much more easily harvested than sugar beets, and they also keep better in winter storage than sugar beets, rutabagas, or turnips. They likewise stand drouth and hot weather better than rutabagas or turnips. Mangels should not be fed until after they have been stored for a few weeks, as the freshly-harvested roots may cause scouring. Half-sugar mangels, which are crosses between sugar beets and mangels, are richer in dry matter and sugar than are mangels.

Mangels are a very satisfactory feed for dairy cows, beef cattle, or sheep, except that they should not be fed to rams or wethers for long periods, because of possible danger from urinary calculi. (632) In New York tests 700 lbs. of mangels equalled 100 lbs. of dried beet pulp in feeding value for dairy cows.[37] For dairy cows, mangels and sugar beets have an advantage over rutabagas and turnips, because there is no danger of tainting the milk.

Fodder beets are considerably higher in dry matter than are mangels, and therefore have a higher value per pound. In English trials 100 lbs. of fodder beets equalled 190 lbs. of mangels for dairy cows.[38] Cows tended to go off feed if fed more than 60 lbs. of fodder beets daily.

642. Sugar beets.—The sugar beet (*Beta vulgaris*, var.) has been so developed for sugar production that some strains now contain 16 per cent or more of cane sugar. The yields are smaller than those of mangels, but owing to the higher sugar content sugar beets generally produce about as much dry matter per acre. However, they require more labor in harvesting than mangels, as they set deep in the ground. They are well liked by stock and are sometimes fed to dairy cows on test. As in the case of mangels, it is not wise to feed sugar beets to rams or wethers for long periods. (632)

The composition and value of beet pulp and beet molasses are discussed in Chapter XXIII.

643. Beet tops.—In harvesting sugar beets for sugar production, the crowns are cut off, because they contain salts which interfere with the recovery of sugar from the juice. When gathered without undue waste, the tops, which include the crowns and the leaves, will weigh from 45 to 75 per cent as much per acre as the marketed beets. Often the tops are purchased, not on the basis of

the weight of the tops, but at a certain price for the tops from each ton of marketed beets.

To utilize the tops, various methods are used: Cattle or sheep may be grazed on the tops in the field. The tops may be put into small piles, allowed to cure out more or less, and then hauled to the feeding yards. Sometimes the tops are ensiled, and occasionally they are dehydrated. Pasturing the tops may be the most economical method of using the tops, if the weather is dry enough to avoid considerable wastage, but does not usually give the maximum feeding value per acre.

Beet tops are decidedly laxative and should therefore be fed in moderation. The silage is less laxative than the fresh tops, but it is best not to feed more than 8 to 30 lbs. per head daily to cattle, depending on their size, or more than 3 lbs. to sheep. Beet leaves contain considerable oxalic acid, which is poisonous if animals receive too large amounts. It is best to feed 2 ounces of finely-ground limestone or chalk with each 100 lbs. of tops, as calcium changes the oxalic acid to insoluble calcium oxalate. Adding the calcium supplement reduces trouble from scouring. The oxalic acid is decreased somewhat in field curing.[39] If there is considerable dirt adhering to the tops, as much as possible should be removed before feeding the tops or ensiling them. Otherwise digestive disturbances may result.

The tops may be fed in larger amounts to cattle and sheep, in proportion to their live weight, than to horses or swine. This is because the fermentations in the paunch of ruminants destroy some of the oxalic acid.

Beet tops are generally ensiled in trench silos or in stacks above ground. The tops should be as green as possible.[40] They need not be run through a silage cutter and need no tramping, as they settle well with their own weight. It is a good plan to allow a period of 2 to 3 days between ensiling each layer of 3 to 4 feet of green tops. Ensiling the tops alone is preferable to the methods sometimes used of ensiling them in alternate layers with straw or in combination with dry fodder or stover.

Beet tops and beet-top silage give the best results when fed with legume or other hay and along with grain, instead of being used as the only roughage. When thus fed as part of a balanced ration, they are satisfactory for fattening cattle, sheep, and lambs, and for dairy cattle. In 15 Nebraska experiments with fattening lambs the beet tops from each ton of sugar beets saved, on the average, 24 lbs. concentrates plus 102 lbs. alfalfa hay, and slightly more rapid gains were secured when beet tops were added to the ration of grain and alfalfa hay.[41]

In Nebraska experiments when beet top silage was fed as the only roughage to fattening lambs, serious death losses of wether lambs occurred from urinary calculi.[42] (252) If alfalfa hay was also fed and the lambs actually ate 0.50 to 0.75 lb. of alfalfa a day, the losses were greatly reduced. Feeding soybean oil meal as the protein supplement also decreased the losses.

The value of beet tops and beet-top silage per ton will vary widely, as there is a large range in the percentage of dry matter contained. In Idaho and Nebraska experiments with fattening lambs a ton of beet-top silage, fed with alfalfa hay, equalled 333 lbs. alfalfa hay plus 85 lbs. grain or other concentrates in feeding value.[43] Beet tops, cured more or less, or beet-top silage has had an even higher relative value for dairy cows, fattening cattle, or fattening lambs in other experiments.[44] On the other hand, in a North Dakota experiment when fattening steers were fed too large an allowance of beet-top silage, they scoured badly and the silage was worth only one-quarter as much as corn silage.[45] On the average, beet-top silage will probably be worth approximately one-half as much per ton as corn silage. If dairy cows are fed moderate amounts of beet-top silage after milking, the flavor of the milk is not affected markedly.[46]

In a New York trial 5 per cent of dehydrated sugar beet leaves was satisfactory as a substitute for alfalfa meal in a ration for chicks.[47] A larger amount depressed growth, unless the percentage of calcium in the ration was increased, to make the oxalic acid insoluble.

644. Rutabagas.—The rutabaga, or swede (*Brassica napobrassica*), which is grown extensively in Great Britain and Canada, ranks next to the mangel in ease of cultivation. Sheep prefer it to all other roots. Rutabagas and turnips do not require such fertile soil as mangels, but do best where the climate is cool. In the central part of the corn belt and southward much of the growing season is too hot for them and they are apt to grow large necks, instead of developing good-sized roots. Like other turnips, rutabagas are apt to taint the milk of cows, unless fed only immediately after milking.

645. Turnips.—Turnips (*Brassica rapa*) are more watery than rutabagas and do not keep so well. Hybrid turnips, crosses between the turnip and the rutabaga, keep better than ordinary turnips. Maturing early,

large yields of turnips are often secured without cultivation. Though used mainly for sheep, they can also be fed to cattle.

646. Carrots.—Carrots (*Daucus carota*) usually yield much less than the root crops previously discussed; they are more particular in their soil and climate requirements; and the cost of growing the crop is higher. They are therefore of little importance for stock feeding. Occasionally, carrots are grown for horses, which are very fond of these roots. Yellow carrots can be used as a source of carotene in poultry feeding.

In Ohio tests carrots were ensiled with corn forage, at the rate of 1 ton of carrots and tops to 2.25 tons of corn, to make a silage especially high in carotene.[48] When fed to dairy cows, this maintained a high vitamin A value and a yellower color in winter milk.

647. Parsnips.—The parsnip (*Pastinaca sativa*) is the favorite root crop with dairymen on the islands of Jersey and Guernsey. Parsnips contain about as much dry matter as sugar beets, but as the yield in this country is relatively low and the roots are difficult to harvest, they are rarely grown here for stock feeding.

648. Jerusalem artichoke.—The tubers of this hardy perennial (*Helianthus tuberosus*) are sometimes grown for human food, for industrial uses, or for feeding livestock. They resemble the potato in composition, except that the chief carbohydrate is inulin, instead of starch. Though artichokes have often been recommended enthusiastically for livestock, they have proved less economical or useful than our common crops and have never been used to any appreciable extent for stock feeding in this country.[49] In various tests the yield of tubers has usually ranged from 6 to 15 tons per acre.

The forage may be cut and used for silage or as a green soiling crop, yielding 5 to 9 tons per acre, but the yield of tubers is greatly reduced by cutting the tops for forage. Artichoke silage does not compare favorably in value with corn silage.

The tubers are difficult to harvest and do not keep well in storage. They live over winter in the ground, and, even when dug in the fall, enough are usually left to make the next crop. Because of this, they may sometimes become a weed. Pigs may be turned in to harvest the tubers, but should be fed grain in addition, as they will make but little gain on artichokes alone. For swine feeding, artichokes are less valuable than corn grown for hogging down, or than other forage crops.

649. Chufa.—The chufa sedge (*Cyperus esculentus*), frequently a weed in damp fields on southern farms, produces small, chaffy tubers that remain in the ground uninjured over winter. In certain sections of the South chufas are often used for fattening swine, which are turned in to harvest the crop.[50]

Chufas grow best on sandy soils, yielding 36 bushels of 44 lbs. each per acre in Florida tests. As they are very low in protein, they should be supplemented by protein-rich feeds. Good crops of chufas have made 296 to 613 lbs. of pork per acre, after making allowance for the other feed consumed by the pigs. However, they produce a soft carcass which can be hardened only by prolonged feeding of hardening feeds.

650. Cassava.—Cassava (*Manihot utilissima*), a bushy tropical plant with fleshy roots like sweet potatoes, can be grown in Florida and along the Gulf Coast. Cassava is used for the manufacture of tapioca starch or for feeding cattle or swine. The growing of cassava in this country has declined, because other crops give larger yields at less expense.

From 5 to 6 tons of roots, containing 25 to 30 per cent of starch, are produced per acre. Some varieties contain much prussic acid and must be heated or dried before feeding, to drive off this poison. The varieties grown in this country are not poisonous. In Hawaiian tests the results were satisfactory when cassava roots supplied not over one-third the dry matter in rations for pigs, but a greater proportion for pigs or dairy cows caused scours.[51]

The value of *dried cassava meal*, or manihot meal, the by-product from cassava starch factories, is discussed in Chapter XXIII.

II. Miscellaneous Succulent Feeds

651. Rape.—Dwarf Essex rape (*Brassica napus*), one of the cabbage family, is often grown in the northern and central part of the United States as a temporary pasture crop or as a soiling crop. Rape provides excellent forage over a long season; it is easily grown and requires no cultivation; it thrives on any fertile soil adapted to corn; and the seed is cheap. Rape pasturage has a high nutritive value, for the leafy portions are nearly as rich as alfalfa in protein, on the dry matter basis. Since the young

plants are not injured by light frosts, rape may be seeded in early spring and should be 8 to 10 inches high and ready for grazing 7 or 8 weeks later. If not pastured too heavily, the crop will provide forage until late in the fall, for the plants are not killed by ordinary frosts. Rape should never be grazed so closely that only the bare stalks remain, or the new growth will be greatly reduced. Rape is not satisfactory for silage.

Although rape commonly produces the best yield when sown early in the spring, it will make a satisfactory crop when seeded as late as June or early in July, if sufficient moisture is available. For fall feeding, rape may be sown in corn previous to the last cultivation, and it is sometimes seeded in spring grain. In the South rape is an excellent winter forage crop for fertile soils.

Rape is used chiefly as a pasture crop for swine and sheep. It is also satisfactory for cattle, but dairy cows should be fed rape or grazed on the crop only immediately after milking, to avoid tainting the milk. Access to clover or bluegrass pasture when on rape is advantageous for cattle and sheep, as it reduces the danger from bloat. Sometimes stock must be accustomed to rape, but later they become fond of it. Animals on rape should have plenty of salt, as this checks any undue laxative effect.

Rape Excels as an Annual Forage Crop in the North

At small expense rape furnishes excellent pasturage from early summer to late fall.

Rape requires a rich soil and does best in a moist, cool season. In Ontario, Canada, an average of 19 tons of rape forage per acre was secured in tests over 15 years.[52] Under unsuitable conditions rape does not do well and also is often seriously damaged by plant lice.

In the northernmost states rape is often seeded for pasture in combination with oats and peas, or with only oats or barley. The combination furnishes even earlier feed than rape, and if conditions are favorable, the rape comes on after the other forage is grazed off, and lasts until late fall. In Wisconsin tests oats-peas-and-rape pasture or oats-and-rape had a little higher value for pigs than rape alone, but farther south, or in other sections where field peas do not thrive so well, rape is superior to such a mixture.[53]

Rape is more widely grown in this

country for sheep pasture than any other annual crop. It is used chiefly as a supplement to permanent pastures when they become scanty in midsummer and later. Rape or mixtures including rape were decidedly superior to bluegrass pasture for lambs in Ohio and Wisconsin tests, but in Kentucky excellent bluegrass pasture was nearly equal to rape or rape mixtures.[54]

As rape may cause bloat in sheep, the same precautions should be taken as with alfalfa. (**49**) A combination of oats and rape is less apt to cause bloat than rape alone. Allowing lambs to graze on rape when it is wet or too immature may cause scours. It is best to keep sheep, especially lambs, off a field of rape drenched with dew or rain until the leaves are dry. Often shepherds cut rape and feed it as a green soiling crop, instead of pasturing it. This is safer but takes considerable labor. Rape may be pastured late in the fall, even after it freezes, though there may then be more danger of bloat.

Rape or a combination including rape is the best annual pasture crop for swine where rape thrives. Experiments have shown clearly that such pasture is nearly equal to alfalfa or red clover in value per acre. (**466, 472**) Where alfalfa thrives, it slightly excels rape, chiefly because it need not be reseeded each year and also because it is a legume and thus builds up the soil. Though the portion of rape plants eaten by pigs is nearly as rich as alfalfa in protein, pigs self-fed, free choice, corn and a protein supplement generally eat a somewhat greater amount of supplement on rape than if on alfalfa or clover.

Rape occasionally causes blistering or sunscalding of swine, especially of white ones. This may occur when pigs graze in rape when it is wet and then get into hot sunshine. Care should be taken to rub crude oil, vaseline, or lard on any blistered spots. As very little trouble is generally experienced, even with white pigs, one should not hesitate to use rape for swine pasture.

A large-growing variety of rape, called "giant rape," or "broad-leaved rape," is often grown in Great Britain but is not common in the United States. In New York tests this variety furnished slightly more grazing for sheep than Dwarf Essex rape.[55]

Rape is sometimes fed as a green feed to poultry, or rape may be used for poultry pasture. Rape produces very dark colored egg yolks.

652. Cabbage.—On rich ground cabbage (*Brassica oleracea*) produces as much palatable forage as do root crops, but because more labor is required in its cultivation, it is grown but little for stock feeding. Cabbage is prized by shepherds when preparing stock for show, and is also used for feeding poultry and milk cows. Like other plants of the mustard family, it should be fed after milking, to avoid tainting the milk. When cabbage is raised for market, the small heads and the leaves may be fed to stock, unless the leaves carry too much poisonous spray residue.

653. Kohlrabi.—Another member of the cabbage family, kohlrabi (*Brassica caulorapa*), can be grown wherever rutabagas thrive. Under favorable conditions for rutabagas, kohlrabi yields less, but in hot weather it does better than rutabagas. Since the thickened, turnip-like stems stand well above the ground, the crop is readily pastured by sheep, which also relish the leaves. Kohlrabi apparently does not taint the milk when fed to dairy cows.

654. Kale; marrow-stem kale.—Kale (*Brassica oleracea*, var. *acephala*), a cabbage-like plant that does not form heads, is grown extensively for stock feeding in this country only in the northern Pacific-Coast district. A large-growing variety, "thousand-headed kale," is there considered the best fall and winter soiling crop for dairy cows and is also used for sheep and swine. In that district kale will usually remain green most of the winter.

In Oregon tests 131 lbs. of kale equalled 100 lbs. of corn silage for dairy cows, and the yield of kale was so much higher than that of corn that an acre of kale was worth 2 acres of corn silage.[56] Kale, like others of the mustard family, should be fed after milking to avoid tainting the milk.

Marrow-stem kale, a kind with enlarged, fleshy stems, is used to some extent in Great Britain as a soiling crop, especially for sheep. It is also sometimes ensiled, being chopped and preferably mixed with straw or hay, as it is very low in dry matter.[57]

655. Sunflowers as a forage crop.—Where the season is too short and cool for corn, sunflowers (*Helianthus annuus*) are sometimes used for silage and as a green soiling crop. Sunflowers are not affected so much as corn by cool weather or injured by light frosts, and therefore produce a good crop where corn would fail. Sunflowers should be ensiled when one-half to two-thirds of the heads are in bloom. If cut later the forage is less palatable, and the heavy heads make the forage difficult to handle, as it is top-heavy.

Sunflowers are inferior to corn for silage where the latter thrives, even though they will often yield more forage per acre. This is because the silage is decidedly less palatable and is much lower in feeding value. Average sunflower silage has only 12.2 per cent of total digestible nutrients, compared with 18.3 per cent for well-matured corn silage. For dairy cows [58] and for beef cattle [59] good sunflower silage has usually been worth much less per ton than corn silage or sorghum silage. Its value has been more similar to oat-and-pea silage or oat-vetch-and-pea silage. The value of sunflower silage has been especially low per ton in comparison with that of well-matured corn silage, in tests where pigs have followed the cattle to utilize the unchewed corn kernels in the manure. For sheep sunflower silage has also generally been much inferior in value per ton to good corn or sorghum silage, or even to that from peas and oats or peas and barley.[60]

When stock are accustomed to good corn silage, it is sometimes difficult to get them to take sunflower silage, but they can usually be induced to eat it, if it is mixed with more palatable feed. Sunflower silage is sometimes rather constipating and had best be fed with laxative feeds, such as legume hay.

Sunflowers are sometimes grown in combination with corn for silage in cool regions, with the hope of securing a larger yield or a surer crop than from corn alone, and obtaining a more palatable silage than from sunflowers alone. If this is done, it is best to plant the corn and the sunflowers in alternate rows, because otherwise the tall-growing sunflowers will tend to choke out the corn.

Considering the rather low palatability and feeding value of sunflower silage, it would generally seem advisable to use a hay crop for silage in regions too cool for corn, instead of growing sunflowers for this purpose.

656. Pumpkins, squashes, and melons.—The pumpkin (*Cucurbita pepo*) is sometimes planted in cornfields and the fruits used as a relish for horses, cattle, and pigs. Pumpkins contain only 10.4 per cent dry matter and their feeding value per ton is therefore low. One ton of pumpkins, including seeds, is about equal in feeding value for dairy cows to 333 to 400 lbs. mixed hay or 800 lbs. corn silage.[61]

Pumpkins are not satisfactory as the only feed for pigs, but they may be fed along with grain and a protein supplement. It will take 10 tons or more of pumpkins to equal 1 ton of grain in feeding value for pigs.[62] Cooking pumpkins for swine is not beneficial. There is a common opinion that pumpkin seeds are harmful to stock, but this is not true.[63] Feeding the seeds alone, however, is apt to cause indigestion on account of the high fat content.

In Colorado hogs have been fattened exclusively on raw *squashes* (*Cucurbita*, spp.). The meat had a good flavor, but the fat had an undesirable yellow color.[64]

Melons, especially pie melons, or citrons, are occasionally fed to stock.[65]

657. Honeysuckle.—In some areas of the southeastern states semi-evergreen honeysuckle vine (*Lonicera*, spp.) grows rampantly over shrubs and up trees in wooded pastures, furnishing some forage for stock. In Georgia tests the young growth, which is the part eaten by stock, was about equal to good grass hay in content of digestible nutrients, on the dry-matter basis, and produced fair gains on young cattle as the only feed.[66]

658. Hydrolyzed sawdust; fodder cellulose.—By heating sawdust with dilute acid under pressure, a portion of the woody fiber can be converted into more digestible compounds, including certain sugars. Cattle will not usually eat the hydrolyzed sawdust unless mixed with well-liked feeds. However, dairy cows have been successfully fed concentrate mixtures containing one-quarter to one-third of the hydrolyzed sawdust. When thus used the feeding value of hydrolyzed sawdust made from either pine or fir has differed greatly in the limited tests made with it.[67] The value has ranged from only one-fourteenth as much as grain to about one-half as much as grain. Because of the expense of producing the hydrolyzed sawdust, the method would be of practical importance only during a prolonged period of serious feed shortage.

"Fodder cellulose" has also been prepared for stock feeding by treating sawdust by a sulfite process, similar to the process used in making paper pulp, which removes the indigestible lignin and leaves mostly

wood cellulose. In the feed shortage in Europe during the recent war, fodder cellulose or paper pulp, gave satisfactory results when fed to ruminants as a partial substitute for other feed. Since it is tasteless, it was usually moistened with molasses to improve the palatability.[68] Using fodder cellulose as the only roughage, or with only straw, for a long time, produced digestive trouble, due to the suppression of the bacterial digestion in the rumen. (45)

659. Mint hay or silage.—Hay or silage can be made from green peppermint (*Mentha piperita*) after the oil is extracted by steam distillation. In a Michigan test mint hay was a satisfactory substitute for alfalfa hay for dairy cows.[69]

660. Pineapple tops.—Chopped pineapple tops, or crowns, which form about 7 per cent of the weight of the fresh fruit (*Ananas comosus*) were palatable and equal to green Napier grass as the only roughage for dairy cows or dairy heifers in Hawaiian experiments.[70] The cows ate 60 lbs. or more of the tops per head daily. Chopped pineapple tops, with molasses as a preservative, made satisfactory silage, but there was an excessive loss by seepage, because of the low dry matter content.

661. Ramie meal.—Ramie meal is a new dehydrated product made from the leaves and tops of ramie (*Boehmeria nivea*), a plant that is grown for fiber in certain sections of Florida and other regions with a climate that is warm enough. It resembles alfalfa meal in protein, carotene, and fiber content. Ramie meal has been satisfactory as a substitute for alfalfa meal for poultry, and may be fed to cattle, mixed with well-liked concentrates.[71]

662. Spurry.—Spurry (*Spergula sativa*), which requires a cool, moist growing season, is sometimes used as a catch crop for feeding green to stock on sandy land in northern Europe. It has proved of little value in this country, not being adapted to our hot summers.

663. Tree leaves and twigs.—The leaves and small branches of trees are sometimes fed to farm animals in certain countries when better feed is scarce. In some of the mountain range areas of this country the leaves and twigs of shrubs form no small part of the forage eaten by stock.

Tree leaves are more digestible than twigs, and the better kinds compare favorably with ordinary hay in feeding value. Leaves of the ash, birch, linden, and elder are valued in the order given. They are eaten with relish, especially by goats and sheep. These statements apply only to leaves gathered at the right stage and cured like hay. Leaves which turn brown and drop from the trees in autumn are worthless for feeding farm animals. Brush feed, consisting of ground and crushed twigs, stems, and leaves, has occasionally been used in certain mixed feeds as an absorbent for molasses.

664. Vegetable wastes.—Vegetable tops, leaves, and other wastes, which are a by-product in preparing such vegetables as carrots, broccoli, turnips, etc., for the table or for dehydration or canning, can be utilized for stock feeding. Dehydrated vegetable wastes of this kind can be used as substitutes for alfalfa meal in poultry feeding, as they are very rich in carotene.[72]

Sometimes dried vegetable wastes are solvent-extracted to produce carotene or other plant-pigment concentrates. The residue of course has no vitamin A value but may be used to replace part of the protein supplement for poultry or cattle.[73]

Cooked potato peelings can be used in swine feeding in the same manner as cooked potatoes, but have a somewhat lower value per pound.[74]

III. Plants of the Arid Districts

665. Sagebrush, saltbush, and the greasewoods.—Many species of sagebrush (*Artemisia*, spp.), saltbush (*Atriplex*, spp.), and greasewood (*Sarcobatus*, spp.) flourish in the arid portions of the West where drouth, alkali, and common salt make conditions unfavorable for most of the ordinary forage crops. On many ranges they furnish much of the feed consumed by stock.[75] The Australian saltbush, introduced into certain sections of the West, has proved of much less value than was first expected. It is less drouth resistant than the native saltbushes and is rather unpalatable on account of its high salt content.[76]

666. Yucca and sotol.—It has been found that various species of yucca (*Yucca*, spp.), including soapweed and the Spanish bayonet, and also sotol (*Dasylirion*, spp.), a near relative of the yuccas, furnish valuable emergency feed for range cattle in the Southwest. Usually the dry leaves are first burned off and then the plants are cut with an axe and hauled to a central location. Here they are finely chopped or shredded by special machines and fed to the cattle. The prepared forage may also be ensiled. The compact heads of sotol are used similarly. Cattle may be maintained on either of these emer-

gency feeds alone through long drouths, when they would otherwise starve.[77]

667. Russian thistle.—The Russian thistle (*Salsola kali*, var. *tragus*), now growing over great areas of the western plains, is used to some extent for pasture, hay, or silage when better feeds are scanty on account of drouth.[78] The mature plants are woody, spiny, loaded with alkali, and very unpalatable. For hay Russian thistles should be cut when in bloom, before the spines harden and the plants become woody. If the plants are too mature when made into hay, the hay should be sprinkled with water several hours before feeding, to soften the spines. Even early-cut Russian thistle hay is best fed in chopped form as only part of the roughage. If stock will not eat it satisfactorily, sprinkling it with diluted molasses will help.

Silage made from Russian thistles may be very unpalatable unless molasses is added as a preservative, or unless thistles that are rather immature and low in dry matter are wilted before ensiling them.

668. Kochia, or burning bush.—Kochia (*Kochia scoparia*), also called burning bush, fireball, fireweed, or summer cypress, is a large coarse annual that is sometimes grown as an ornamental, because of its fiery autumnal color. It has become established as a weed in some districts. South Dakota tests indicate that when kochia is cut before flowering it makes satisfactory, leafy hay, which supplies nearly as much total digestible nutrients as alfalfa.[79] Kochia makes satisfactory pasture for cattle, though not equal to alfalfa.[80]

669. Cacti.—During periods of drouth the cacti, especially prickly pears (*Opuntia*, spp.), are a boon to stockmen on the southwestern ranges.[81] Because of their peculiar structure and habits, cacti can survive long drouths, though they make little growth at such times. The prickly pear cacti, which grow wild on the ranges, may be fed where they stand by first singeing off the spines with a gasoline torch, or they may be gathered and run through machines which chop them in such a manner that the spines are comparatively harmless. Cacti grow slowly on the range, and can usually be harvested but once in 5 years, even under favorable conditions.

SINGEING PRICKLY PEAR WITH A GASOLINE TORCH

After the spines have been singed off, cattle can feed on prickly pear without harm. Another method is to cut the cacti and run them through machines which chop them, rendering the spines comparatively harmless. (From U.S. Department of Agriculture.)

Prickly pear cacti contain about 16.6 per cent dry matter, being less watery than roots, and cane cacti (*Cholla*, spp.) contain somewhat more dry matter. Since they are low in protein, all the cacti should be fed with a protein-rich concentrate or roughage. Cacti alone will not maintain stock. Though desert cattle sometimes subsist on them for three months of the year, they become very

emaciated. Fed in large amounts with no dry feed, cacti tend to produce scours.

Spineless cacti, long known but sometimes exploited as a novelty, have only limited usefulness for stock feeding, because on the open range cattle will graze and destroy them and also because they must be enclosed in rabbit-proof fences, for rabbits are fond of them.[82] Spineless cacti will not stand the winters in the northern states.

The chief importance of cacti is to furnish emergency forage for stock in the semi-arid regions in case of drouth, for these plants are able to utilize most efficiently small and irregular supplies of moisture. For this purpose plantations of the spiny cacti may be established on the open range, where they will be able to grow and hold their own until drawn upon in time of serious drouth, for cattle will not graze them when other feed is reasonably abundant.

IV. Poisonous Plants and Poisonous Feeds

In this volume only the briefest mention can be made of some of the most important facts concerning poisonous plants and poisonous feeds. One in trouble should consult a competent veterinarian or his state agricultural college or experiment station.

670. Prussic acid, or hydrocyanic acid poisoning.—Under certain conditions some plants cause the death of stock from prussic acid, or hydrocyanic acid poisoning. Of the several species of plants which may cause such poisoning the most important are the sorghums, Johnson grass, chokecherry, black cherry, arrow grass, velvet grass, Christmas-berry, and Sudan grass.

When the plants are poisonous, the poison is usually not present in appreciable amounts as free prussic acid, but in the form of complex compounds, called glucosides. These must be broken down and the free prussic acid liberated before poisoning occurs. However, the glucosides are readily broken down by an enzyme usually present in the plant. The poison may be set free in the digestive tract of an animal eating the dangerous plants, and it may also be set free in the plants on wilting or being bruised. Cattle and sheep are affected by the poison, but horses and swine are apparently not injured, or only very rarely.

The poisonous property usually develops in dangerous amounts only when the growth of the plants is checked or stopped by drouth, frost, trampling, mowing, or wilting. Freezing that ruptures the plant cells causes a rapid liberation of free prussic acid.[83] Young plants generally contain much more of the poison than when growth is well advanced. Certain seeds, such as vetch seed, may sometimes contain dangerous amounts of the glucosides.

Prussic acid poisoning by the sorghums occurs chiefly in the western plains states, which are especially subject to drouth. Only a few cases have been reported in the humid sections of the South. When sorghum or other forage is thoroughly cured as hay or dry fodder, the poisonous property is usually greatly reduced. Silage that has been stored for several months is generally safe. Sudan grass is much less apt to cause poisoning than the sorghums, and is therefore much safer to use for pasture or for a soiling crop.

Stock affected by the poison often die in a few minutes after eating only a small amount of the dangerous forage, perhaps only a few mouthfuls. Therefore, there is usually no time for treatment. In pasturing sorghums the only safe way is to turn an animal of little value into the field first. If no poisonous effects are observed, the rest of the stock may then be allowed to graze the crop.

Glucose in the rumen checks the rate of formation of the prussic acid, and it has been found that it is wise to give cattle or sheep a starchy feed, such as corn or the grain sorghums, before allowing them to graze on or in the vicinity of plants that may be dangerous. The starch in the grain forms glucose in the digestive tract and thus aids in preventing trouble.

If a poisoned animal is discovered in time, a drench of molasses diluted with water may be helpful, but a veterinarian should be called at once to give additional treatment.

671. Ergot.—The seeds of rye and of certain grasses, especially Dallis grass and Argentine Bahia grass, are sometimes attacked by the ergot fungus, which changes the seed into enlarged black masses. This ergotized seed is poisonous to stock if consumed in appreciable amounts. Injury to stock on pasture of Dallis grass or other grass affected by ergot can be prevented by not allowing the grass to go to seed.

Rye grain containing ergot may injure animals continuously fed it. The poor results often secured when rye grain forms a large part of the ration for pigs may be due in part to ergot in the grain. In a Montana experiment when brood sows were fed grain containing not over 1 per cent of ergot during pregnancy, many of their pigs were so weak that they died soon after birth, and the sows

showed almost complete lack of udder development.[84]

Animals showing any symptoms of injury from ergot should have their feed changed and should be warmly housed and liberally supplied with nourishing feed.

672. Scabbed grain.—Sometimes barley and other small grain is seriously affected by the fungus which causes scabbed kernels. Scabbed grain does not injure cattle, sheep, or poultry.[85] On the other hand, horses refuse grain that is very scabby. Pigs also will not eat much badly scabbed grain and are made sick if more than about 10 per cent of the ration consists of scabbed barley kernels.

673. Smut on corn and other grain.—Corn forage or corn ears affected by smut are apparently harmless to stock, though animals may possibly be injured if fed large amounts of smut separated from such corn.[86] There is no need of removing the masses of smut from corn forage as it is being fed or ensiled or of removing smut from dry fodder. Grain sorghum smuts are also not injurious to stock,[87] and wheat damaged by stinking smut did not injure poultry in a Maryland test.[88]

674. Spoiled or moldy feed; forage poisoning; botulism.—Many cases have been reported in which the death of stock, especially of horses, has apparently been caused by the eating of spoiled feed. From time to time serious losses of horses and cattle have occurred, particularly in the Mississippi Valley, from so-called "forage poisoning," or "corn-stalk disease." Such trouble occurs most frequently in stock grazing on cornstalk fields or fed spoiled corn forage or corn silage. Investigations have not yet revealed the exact cause of such trouble, though it is apparently caused by the spoiled feed. In turning stock on stalk fields, especially when the crop was not well ripened, it is a good plan to put one or two of the least valuable animals in first, and watch results closely.

Most of the common molds are not at all poisonous, and therefore feed which is badly molded may be entirely harmless. On the other hand, certain molds are dangerous, and the presence of mold may indicate that other changes may have taken place which may produce poisons, as in the case of damaged sweet clover hay or silage. Horses are most susceptible to injury from spoiled feed, and sheep are also affected more often than cattle. Great care should therefore be taken not to feed spoiled silage or other feed to these two classes of stock. Hay which is slightly moldy (except sweet clover hay) is not ordinarily dangerous, though it tends to cause trouble from heaves in horses. Sweetclover disease, caused by damaged sweetclover forage, has been discussed previously. (480)

Cattle are rarely affected by feed that is slightly moldy or spoiled, and usually they may be fed silage with traces of mold without danger. Any large masses of spoiled silage should be discarded, and should be placed where horses or sheep cannot eat it. Swine are not usually affected by moderately moldy feed, though they are injured by scabbed barley, as has been pointed out previously in this chapter. However, sometimes moldy corn may kill pigs. For example, the death of 25 out of 100 pigs on a North Dakota farm was apparently caused by a particular kind of mold.[89]

Occasionally, livestock are poisoned by botulism, because of the toxin produced in certain materials by the anaerobic botulinus organism. Horses, mules, and poultry are more susceptible to the poisoning than other stock. While the dangerous feed is often spoiled or moldy, in some cases it is unfortunately normal in appearance.[90] Botulism has occurred in animals on pasture which have been forced to drink stagnant water, doubtless due to the water having passed through spoiled vegetation. Decayed carcasses of animals or bones are apt to be dangerous. Suspected samples of feed should never be tasted by persons, as mere traces of the poison may prove fatal.

In case of suspected botulism or other forage poisoning, the feed should be changed and a competent veterinarian consulted. The use of antitoxin is beneficial in cases that are not too far advanced.

675. Various poisonous plants.—A considerable list of plants are definitely poisonous to stock, and particularly on the western ranges serious losses of stock sometimes occur from poisoning.[91] Some plants are dangerous only at certain stages of growth, and some affect one class of animals but not others.

Stock seldom eat poisonous plants by choice, but only when induced or compelled to do so by the scarcity of other feed.[92] When the grazing is scanty, the animals should therefore be kept away from spots definitely known to be infested with such plants. In moving herds or flocks on the range, special precautions should be taken when it is necessary to pass over a trail that has been used by many other animals, for all good feed will have been consumed, and the stock will eat whatever is left.

Among the plants that may cause serious trouble on the western ranges are larkspurs, loco weeds, lupines (from the time the pods appear), death camas, bitterweed, greasewood (early in spring), certain milkweeds, water hemlock (tubers and young shoots), woody aster, halogeton, and some vetches.

Most of these plants are poisonous because of toxic alkaloids they contain. Halogeton is poisonous because it has on the dry basis as much as 20 per cent of soluble oxalates (salts of oxalic acid). In the body these oxalates form insoluble calcium oxalate, thus using up the supply of calcium in the tissues. The animal dies as a result of extreme calcium deficiency.

Hungry animals are most susceptible to halogeton poisoning, because they eat more halogeton, even though it is not palatable. Also, if there is considerable other food in the rumen, some of the soluble oxalates will be destroyed in the rumen fermentations or converted there into insoluble calcium oxalate.[93] When animals must be trailed through an area heavily infested with halogeton, they can be protected to a large degree by feeding once a day pellets containing a high amount of calcium supplement.[94] Halogeton is usually more dangerous in the fall than in late winter, when the soluble oxalates have been leached out to some extent.

Other important plants which may cause poisoning are the common brake fern or bracken, mountain and sheep laurel, certain nightshades, cocklebur (young plants before the leaves are developed, and also the seeds), corn cockle, horse tail rush, potato tops, and the foliage of tung trees. It is of interest that bracken and also horse tail rush are poisonous because they contain an enzyme which destroys the vitamin thiamine in the food. White snakeroot and rayless goldenrod not only cause a poisoning of stock, called "trembles," but also the milk produced by affected animals may cause the same poisoning in humans or suckling animals.

Mustard seed and rape seed contain glucosides that may produce poisonous volatile oils when the seed is eaten. These seeds may therefore be dangerous, and also mustard-seed or rape-seed oil cake from which the dangerous property has not been removed. Castor beans and castor-bean oil meal are very dangerous to stock.

676. Selenium poisoning.—It has been found that certain shale soils in areas of considerable size in some of the western states contain appreciable amounts of selenium, a mineral which is poisonous to animals. Some plants, including woody aster, certain vetches, and Nuttall's saltbush, accumulate the selenium in their tissues, and are poisonous only when growing on these soils. When these plants die and decay, other plants, even the grasses or cultivated crops, may take up the selenium and become toxic. The poisoning known as "alkali disease" and "blind staggers" in certain northern range areas is due largely to this cause.

A very small amount of certain arsenic compounds in the feed or water largely or entirely counteracts the injurious effects of selenium in such forage.[95] Excellent results have been secured when 25 parts of arsenic, in the form of sodium arsenite, have been added per million parts of the salt supplied to the stock on ranges where trouble from selenium poisoning has previously occurred. (1.9 grams of sodium arsenite per 100 lbs. of salt supplies this amount. The arsenite must be mixed with the salt with extreme care, as it is itself poisonous.) Certain arsonic acid compounds (arsanilic acid and 3-nitro-4-hydroxyphenylarsonic acid), which are less toxic than sodium arsenite, were effective in counteracting selenium toxicity in recent South Dakota experiments with pigs.[96] The feeding of protein supplements and a plentiful supply of vitamin A seem to help to prevent selenium poisoning.[97]

677. Nitrate poisoning.—In semi-arid regions and during drouth in other areas, nitrate occasionally accumulates in small grain forage and other plants in poisonous quantities.[98] (584) Plants injured by 2,4-D or other weed killers may have dangerous amounts of nitrate.

Most of the cases of nitrate poisoning reported have been caused by oat hay or oat straw, but rarely forage from wheat, barley, sorghum, corn, or weeds may have a dangerous amount of nitrate. Cattle are much more apt to be affected than are sheep or horses. The occurrence of a dangerous quantity of nitrate in forage can be detected only by chemical analysis. Therefore certain of the western experiment stations make, for a small charge, nitrate determinations in forage samples sent in by farmers.

The nitrate in the forage is changed to nitrite in the digestive tract. When this is absorbed into the blood, it changes the hemoglobin into a form that cannot transport oxygen and the animal is asphyxiated.

678. Other poisoning of farm animals.—Many cases of livestock poisoning occur through animals having access to poisonous

substances, such as spray materials, paint, or fertilizer, which have been carelessly left around. Such losses can be avoided by great care on the part of every person handling these materials. All lead paint is poisonous. Animals will not only lick newly painted surfaces or discarded paint containers, but may even lick enough lead paint off an old fence or building to be poisoned.

Animals will not usually eat enough common salt to be injured at all, but if a strong brine is left where they have access to it, they may drink enough to be harmed.

When forage crops are sprayed or dusted with the proper amount of a recommended insecticide or fungicide, the hay, silage, or pasture forage does not contain enough of the spray material to injure livestock. The animals should be removed from a pasture while it is being treated.

In the case of dairy cows fed forage that has been treated with certain insecticides, including DDT, chlordane, toxaphene, and dieldrin, the insecticide may pass into the milk in sufficient amounts to be detectable.[99] If fattening animals are fed such forage up to the time of slaughter, the meat may have a detectable amount of the insecticide.[100] Methoxychlor, aldrin, or heptachlor could not be detected in the milk of cows fed forage treated with a proper amount of the insecticide.[101]

Seed grain that has been treated with mercurial or certain other fungicides should not be fed to stock.

It has been found recently that X-disease, or hyperkeratosis, a serious disease which has sometimes occurred in cattle, is caused by highly chlorinated naphthalenes in certain lubricants and other petroleum products.[102] Because of their excellent lubricating quality under pressure, these compounds have been added to some greases and oils for lubricating machinery. They also occur in certain wood preservatives and asphalt products.

X-disease affects chiefly cattle, and sheep are much less susceptible to injury. The disease, which may be fatal, causes great thickening of the skin, which becomes hard, dry, and wrinkled. It also produces lesions in the mouth and on other mucous membranes, diarrhea, and other symptoms. Part of the toxic effect of these compounds seems to be an anti-vitamin A action, in interfering with the conversion of carotene into vitamin A.

Because of the danger from X-disease, cattle should be kept away from all products that might be dangerous, such as used crank case oil and old oil drums. Drainage from grease racks or farm machinery sheds should not be allowed to contaminate exercise lots or pastures.

QUESTIONS

1. Why are roots unimportant for stock feeding in the United States? Under what special conditions may the use of roots for feeding be advisable in this country?
2. Discuss the composition and feeding value of roots.
3. Compare the economy of roots and corn silage for stock feeding.
4. What have experiments shown concerning the value of roots for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) swine; (e) poultry?
5. Discuss the value and use for stock feeding of any of the following that may be of importance in your district: (a) Potatoes; (b) sweet potatoes; (c) sweet potato vines; (d) mangels; (e) sugar beets; (f) sugar beet tops; (g) rutabagas; (h) turnips; (i) carrots; (j) parsnips; (k) artichokes; (l) chufas; (m) cassava.
6. State the characteristics of rape and discuss its use in stock feeding.
7. Are any of the following fed to stock in your region? If so, how is the forage used: (a) Cabbage; (b) kohlrabi; (c) kale; (d) sunflowers; (e) pumpkins, squash, or melons; (f) vegetable wastes.
8. If the following are of importance in your section, tell how they may be used in stock feeding: (a) Sagebrush, saltbush, and the greasewoods; (b) yucca and sotol; (c) Russian thistle; (d) cacti.
9. Tell the main facts concerning the following: (a) Prussic acid poisoning of stock; (b) ergot; (c) scabbed grain; (d) smut on grain; (e) spoiled or moldy feed; (f) botulism.
10. What general precautions should be taken to avoid injury to stock from poisonous plants?
11. Does selenium poisoning or nitrate poisoning occur in your region?

REFERENCES

1. Haecker, Minn. Rpt. 1913; Wing and Savage, N.Y. (Cornell) Bul. 268; Fries, Denmark, abstracted in Expt. Sta. Rec., 14, 1903, p. 801.
2. Payne, Irish Free State, Dept. Lands and Agr. Jour., 27, 1927, pp. 33–35; see also: Mor-

row, Dustman, and Henderson, West Va., Jour. Agr. Res., 43, 1931, pp. 919–930.
3. Shaw and Norton, Mich. Bul. 240; Morrison and Humphrey, Wis., unpublished data; Rothwell, Canada Dept. Agr. Bul. 94.
4. Brooks, Mass. (Hatch) Rpt. 1893; Horwood and Putnam, Mich. Quar. Bul., 15, 1932, No. 1; Wing and Savage, N.Y. (Cornell) Bul. 268; Thorne et al., Ohio Bul. 50; Kuhlman, McGilliard, and Weaver, Okla. Rpt. 1930–32; Caldwell, Penn. Rpt. 1890; Hills, Vt. Rpt. 1895; Henderson and Morrow, West Va. Bul. 256; Hopkins, Rothwell, Elford, and Schutt, Canada Dept. of Agr. Bul. 94.
5. Kuhlman, Becker, McGilliard, and Weaver, Okla. Rpts. 1924–26, 1926–30; Rothwell, Canada Dept. Agr. Bul. 94; Ste. Marie, Canada Expt. Farms, Rpt. 1930–32; Ste. Anne de la Pocatiere (Que.) Sta., Rpt. Supt. 1923.
6. Fishwick, Jour. Min. Agr., Great Britain, 31, 1924, pp. 50–58; McCandlish and McVicar, Scot. Jour. Agr., 9, 1926, pp. 194–201; Oldershaw, Jour. Roy. Agr. Soc., England, 86, 1925, pp. 112–128; Rae and Gardner, Jour. Min. Agr., Great Britain, 31, 1924, pp. 261–266; 32, 1925, pp. 635–639; Robertson and Pitcher, Jour. Min. Agr., Great Britain, 28, 1921, pp. 506–515; White and Roberts, Jour. Min. Agr., Great Britain, 29, 1922, pp. 34–37.
7. Day, Ont. Agr. Col., Canada, Rpts. 1901, 1902; Blair, Rpt. Dominion Expt. Farms, Canada, 1917, p. 72.
8. Wilson, S.D. Bul. 137.
9. Kennedy, Robbins, and Kildee, Iowa Bul. 110; Smith and Mumford, Mich. Bul. 113; Arkel, N.H. Bul. 152; Hackedorn, Sotola, and Singleton, Wash. Bul. 258.
10. Morrison and Kleinheinz, Wis. Buls. 388, 396; Roche, Morrison, Bohstedt, and Kleinheinz, Wis. Bul. 410; Humphrey and Kleinheinz, Wis. Bul. 275; see also: Hackedorn, Singleton, and Sotola, Wash. Bul. 351.
11. Michael, Iowa Bul. 112; Pontius, Carr, and Doyle, Ind., Jour. Agr. Res., 42, 1931, pp. 433–446.
12. Hudson, Mich. Rpt. 1926.
13. Morrison, Bohstedt, and Fargo, Wis. Bul. 362.
14. Plumb, Ind. Buls. 79, 82; Shaw, Mont. Bul. 27; Lazenby, Ohio Rpt. 1884; Sanborn, Utah Rpt. 1891; Clark, Utah Bul. 101; Robertson, Ottawa, Canada, Expt. Farms, Rpt. 1891.
15. Fausch and Kiser, Minn. Farm and Home Sci., 9, 1951, No. 1.
16. Dice, N.D. Buls. 233, 249.
17. Atkeson and Anderson, Id. Bul. 216; Dice, N.D. Buls. 233, 249; see also: Huffman and Baltzer, Mich. Exten. Bul. 73; Keyes and Nelson, Mont. Bul. 467.
18. Hills, Vt. Rpt. 1898.
19. Morton, Maynard, and Osland, Colo. Press Buls. 74, 77; Maynard, Colo. Exten. Bul. 276a; Hickman, Rinehart, and Johnson, Id. Bul. 209; Hackedorn, Sotola, and Bean, Wash. Bul. 229; Patterson, Highl. and Agr. Soc., Scotland, Trans., 5 ser., 43, 1931, pp. 86–89.
20. Fausch and Kiser, Minn. Farm and Home Sci., 7, 1949, No. 1; 9, 1951, No. 1.
21. Maynard, Morton, and Osland, Colo. Bul. 379; Morton, Maynard, and Fairbanks, Colo. Press Bul. 76; Rinehart, Hickman, and Johnson, Id. Bul. 194; Hodgson et al., Id. Bul. 272; Holden, Nebr. Bul. 216; Hackedorn, Sotola, and Singleton, Wash. Bul. 258; Hackedorn and Singleton, Wash. Bul. 325.
22. Woodman and Evans, Jour. Agr. Sci., England, 33, 1943, pp. 155–168.
23. Wilson and Kuhlman, S.D. Bul. 209; Swier, Wash. Bul. 291.
24. Connell, Tom, and Wheeler, Colo. Tech. Bul. 37.
25. Kennard, Ohio Bimo. Buls. 182, 243; see also: Klooster and Card, Mich. Quar. Bul., 19, 1936, No. 2.
26. Experiments summarized by Heuser, Feeding Poultry, 2nd Ed., 1955, pp. 130–132.
27. Shepherd, Woodward, and Melin, U.S.D.A. Tech. Bul. 914; Connell, Tom, and Wheeler, Colo. Tech. Bul. 37; Johnson, Rinehart, and Hickman, Id. Bul. 293; Archibald and Parsons, Mass. Bul. 428; Turk, N.Y. Farm Res., 11, 1945, No. 1; Allender, U.S.D.A. Misc. Pub. 676.
28. Breirem and Husby, Norway, Norsk Landbruk, 17, 1951, pp. 59–64, 89–93.
29. U.S.D.A. Cir. 714.
30. Seath, Rusoff, Miller, and Branton, La. Bul. 423.
31. Duncan, Tenn. Rpt. 1945; Massey, Ga. Bul. 200.
32. Bray and Francioni, La. Bul. 236; see also: Duggar, Ala. Buls. 93, 122; Shealy and Sheely, Fla. Bul. 236; Edwards and Massey, Ga. Bul. 181; Henke, Hawaii Bul. 99; Patterson, Md. Bul. 63; Hostetler et al., N.C. Rpt. 1928; Newman and Pickett, S.C. Bul. 52; S.C. Rpt. 1922; Nobles, Va. Bul. 246.
33. Godbey and Starkey, S.C. Rpt. 1945.
34. La. Bul. 262.
35. Ga. Rpt. 1944.
36. Grimes, Ala. Rpts. 1942, 1944; N.C. Spec. Cir. 3; N.C. Rpt. 1944.
37. Harrison and Lee, N.Y. (Cornell) Rpt. 1940.
38. Bailey, Castle, and Foot, England, Empire Jour. Exptl. Agr., 21, 1953, pp. 42–48; Line and Cheetham, England, Nat. Inst. for Res. in Dairying, Rpt. 1953.
39. Guilbert, Miller, and Goss, Cal. Bul. 702.
40. Maynard, Beets and Meat, Rev. Ed., 1950.
41. Holden, Nebr. Buls. 194, 216, 268, and mimeo. rpt.
42. Harris and Alexander, Nebr. Quar., 2, 1953, No. 2.
43. Johnson, Id. Bul. 244; Holden, Nebr. Bul. 216.
44. Morton, Osland, and Tom, Colo. Press Buls. 90, 92; Johnson, Rinehart, and Hickman, Id. Bul. 255; Vinke and Hansen, Mont. Exten. Cir. 26; Harris, Davis, and Swanson, Nebr. Bul. 353; Ingraham, Wyo. Buls. 216, 227; see also: Mich. Cir. Bul. 175; Peters and Kiser, Minn. Bul. 404; Hoffman and Bogart, Ore. Bul. 479; S.D. Rpts. 1938, 1941.
45. Christensen, N.D. Bimo. Bul. 3, 1940, No. 2.
46. Trout and Taylor, Mich. Quar. Bul., 18, 1935, No. 1.
47. Heuser, Robertson, and Norris, N.Y. (Cornell) Rpt. 1947.
48. Perkins et al., Ohio Bimo. Bul. 226.
49. Boswell et al., U.S.D.A. Tech. Bul. 514; Rusk, Ill. Rpt. 1932; Evvard and Culbertson, Iowa, mimeo. rpt.; Cormany, Mich. Quar. Bul. 10, 1928, No. 4; Schoth, Ore. Cir. 89; Pittman, Utah Bul. 209; Campbell, Reading Univ. (England) Bul. 35.
50. Shealy and Sheely, Fla. Bul. 236; Killinger and Stokes, Fla. Bul. 419; Ga. Coastal Plain Buls. 32, 35, 36.
51. Hawaii Rpt. 1920.

52. Zavitz, Ont. Dept. Agr. Bul. 228.
53. Morrison and Bohstedt, Wis. Bul. 323; Robison, Ohio Bul. 552; McCarty and Grimes, Penn. Bul. 254.
54. Hammond, Ohio Bul. 340; Craig. Wis. Rpt. 1897; Horlacher, Ky. Cir. 38.
55. Willman, N.Y. (Cornell) Rpt. 1934.
56. Jones and Brandt, Ore. Bul. 272.
57. Jour. Min. Agr., Great Britain, 50, 1943, pp. 77–78; Wood, Jour. Min. Agr., Great Britain, 50, 1943, pp. 315–316.
58. Woll et al., Cal. Rpts. 1922, 1923; Morton, Colo. Rpt. 1920; Ga. Rpt. 1922; Atkeson, Idaho Bul. 215; Nevens, Ill. Bul. 253; Ind. Rpt. 1923; Mich. Quar. Bul., 2, 1920, No. 4; Cole, Donovan, and Allen, Minn. Spec. Bul. 181; Tretsven, Mont. Bul. 282; Quesenberry, Cunningham, and Foster, N. Mex. Bul. 126; N.D. Bul. 159; Jones, Ore. Bul. 194; Bechdel, Penn. Bul. 172; Woodward, Wash. Bul. 158; Henderson and Gifford, West Va. Bul. 210; Holden et al., Wis. Buls. 319, 323; Quayle, Wyo. State Farms Bul. 3, 1922; Moseley, Stuart, and Graves, U.S.D.A. Tech. Bul. 116; Bowstead and Sackville, Univ. of Alberta, Canada, mimeo. rpt.; Canada Expt. Farms, An. Husb. Div., Interim Rpt. 1922; Canada Expt. Farms, Agassiz (B.C.) Farm, Rpt. Supt. 1923; Canada Expt. Farms, Fredericton (N.B.) Sta., Rpt. Supt., 1923.
59. Ariz. Rpt., 1922; Osland, Colo. Bul. 380; Buchanan, Miss. Bul. 278; Arnett, Mont. Rpt., 1923; Quesenberry, Cunningham, and Foster, New Mex. Bul. 126; Christensen, N.D. Buls. 174, 217; Blizzard, Okla. Buls. 134, 139, 147; Wilson and Kuhlman, S.D. Bul. 199; Hackedorn, Wash. Bul. 175; Hackedorn, Sotola, and Bean, Wash. Bul. 186; Fuller and Morrison, Wis. Bul. 352; Hays, Wyo. Bul. 128; Sackville and Bowstead, Alberta, Canada, Agr. Col., Bul. 8; Rothwell, Canada Expt. Farms, An. Husb. Div., Rpt. 1922.
60. Maynard, Morton, and Osland, Colo. Bul. 379; Joseph, Mont. Bul. 164; Darlow, Okla. Buls. 136, 142; Potter and Dean, Ore. Bul. 198; Hackedorn, Wash. Bul. 158; Hays, Wyo. Bul. 130; Fairfield, Canada Expt. Farms, Lethbridge (Alberta) Sta., Rpts. Supt., 1922, 1923.
61. Lindsey, Mass. Bul. 174; Hills, Vt. Rpt. 1908.
62. Rommel, U.S.D.A., Bur. Anim. Indus., Bul. 47; Sotola, Wash., Amer. Soc. Anim. Prod., Proc. 1927.
63. Masurovsky, Jour. Agr. Res., 21, 1921, pp. 523–539; 27, 1924, pp. 39–42.
64. Cottrell, Colo. Bul. 146.
65. S.C. Rpt. 1931.
66. Noland and Morrison, Ga., Jour. Dairy Sci., 37, 1954, pp. 173–175; see also: N.C. Rpt. 1946.
67. Archibald, Mass. Bul. 230; Morrison, Humphrey, and Hulce, Wis. Bul. 323; Woodward et al., U.S. Dept. Agr. Bul. 1272; Sherrard and Blanco, Jour. Indus. and Engin. Chem., 13, 1921, pp. 61–65.
68. Woodman, Jour. Min. Agr., Great Britain, 50, 1943, pp. 311–313; Hoflund, Sweden, Jour. Amer. Vet. Med. Assoc., 112, 1948, p. 304.
69. Taylor and Anthony, Mich. Quar. Bul., 15, 1942, No. 1.
70. Henke and Maruyama, Hawaii Rpt. 1944–46.
71. Mehrhof, Davis, and Driggers, Fla. Cir. S-20; Becker and Davis, Fla. Rpt. 1953; Seale, Gangstad, and Joyner, Fla. Bul. 525; Squibb, Guzman, and Scrimshaw, Guatemala, Poultry Sci., 32, 1953, pp. 953–957.
72. Tomhave, et al., Del. Bul. 247; Runnels, Waller, Kelley, and Krulick, Del. and U.S.D.A., Poultry Sci., 30, 1951, p. 930; Davis, Mehrhof, Driggers, and Dennison, Fla. Cir. S-37; Willaman and Eskew, U.S.D.A. Tech. Bul. 958.
73. Runnels, Tomhave, Kelley, and Wall, Del. and U.S.D.A., Poultry Sci., 29, 1950, p. 778.
74. Woodman, Jour. Min. Agr., Great Britain, 50, 1943, pp. 311–313.
75. Bidwell and Wooton, U.S.D.A. Bul. 1345; Foster, Lantow, and Wilson, New Mex. Bul. 125; Brown, New Mex. Bul. 135.
76. McKee, U.S.D.A. Bul. 617.
77. Forsling, U.S.D.A. Farmers' Bul. 1428; Foster and Humble, New Mex. Bul. 114; Brown, New Mex. Bul. 133.
78. Morton, Osland, and Brandon, Colo. Press Bul. 80; Aicher and McCampbell, Kan. Rpt. 1934–36; Cave, Riddell, and Hughes, Kan., Jour. Dairy Sci., 19, 1936, pp. 285–290; Mont. Rpt. 1936; Christensen, N.D. Bul. 286; Wilson, S.D. Rpts. 1934, 1935; Olson, S.D. Rpt. 1934; Quayle, Wyo. Bul. 243.
79. Erickson and Moxon, S.D. Bul. 384.
80. Baker and Baker, Nebr. Bul. 414.
81. Vinson, Ariz. Bul. 67; U.S.D.A., Bur. Anim. Indus., Bul. 91.
82. Griffiths, U.S.D.A., Farmers' Bul. 1072.
83. Klosterman et al., N.D. Bimo. Bul., 14, 1951, No. 2.
84. Nordskog and Clark, Amer. Jour. Vet. Res., 6, 1945, pp. 107–116.
85. Roche, Bohstedt, et al., Wis. Buls. 410, 425; Rusk and Snapp, Ill. Rpt. 1929; Dickson, U.S.D.A., Farmers' Bul. 1599.
86. Henry, Univ. of Wis., Rpt. of Board of Trustees, 1881; Smith, Mich. Bul. 137; Wilson and Kuhlman, S.D. Bul. 199; U.S.D.A., Bur. Anim. Indus., Bul. 10.
87. Heller, Caskey, and Penquite, Jour. Agr. Res., 40, 1930, pp. 347–351.
88. Quigley and Waite, Md. Bul. 325.
89. Foss, N.D. Bimo. Bul., 7, 1945, No. 6.
90. Graham, Brueckner, and Pontius, Ky. Buls. 207, 208; Graham, Ill. Exten. Cir. 38.
91. See Muenscher, Poisonous Plants of the United States, for detailed information.
92. March, U.S.D.A., Farmers' Buls. 536, 720; Marsh, U.S.D.A., Bul. 1245; Durrell and Glover, Colo. Bul. 316; Hansen, Ind. Cir. 175; Gates, Kan. Tech. Bul. 25; Stevens, N.D. Bul. 265; Lawrence, Ore. Bul. 187; Beath, Draize, and Gilbert, Wyo. Bul. 200.
93. Morris and Garcia, Puerto Rico, Jour. Dairy Sci., 38, 1955, p. 1169.
94. Utah Farm and Home Sci., 15, 1954, No. 4.
95. Moxon, Rhian, Anderson, and Olson, S.D., Jour. Anim. Sci., 9, 1944, pp. 299–309; Hamstra and Olson, S.D., Jour. Anim. Sci., 13, 1954, p. 1003; Wyo. Rpt. 62.
96. Wahlstrom, Kamstra, and Olson, S.D., Jour. Anim. Sci., 14, 1955, pp. 105–110.
97. Moxon, Anderson, and Olson, S.D. Rpt. 1940; Wyo. Rpt. 62.
98. Muhrer, Case, Garner, and Pfander, Mo., Jour. Anim. Sci., 14, 1955, p. 1251; Whitehead and Moxon, S.D. Bul. 424; Gilbert, Eppsom, Bradley, and Beath, Wyo. Bul. 277; see also: Fla. Rpt. 1953.
99. Biddulph et al., Utah Farm and Home Sci., 12, 1951, No. 3; Harris et al., Utah, Jour. Nutr., 51, 1953, pp. 491–505; Bateman et al., Utah, Jour. Agr. and Food Chem., 1, 1953, pp. 322–324; Ely et al., U.S.D.A.,

Jour. Dairy Sci., 35, 1952, pp. 266–271; 37, 1954, pp. 1461–1465; Carter et al., U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 1172–1177.
100. Harris et al., Utah, Jour. Anim. Sci., 10, 1951, pp. 581–591; Wilson et al., Wis. Bul. 474; Carter et al., U.S.D.A., Jour. Anim. Sci., 7, 1948, pp. 509–510; Thomas et al., U.S.D.A., Jour. Dairy Sci., 34, 1951, pp. 203–208.
101. Biddulph et al., Utah, Jour. Dairy Sci., 35, 1952, pp. 445–448; Ely et al., U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 309–314; 37, 1954, pp. 294–298; 38, 1955, pp. 669–672.
102. Olafson and McEntee, N.Y., Cornell Vet., 41, 1951, pp. 107–109; McEntee, Hansel, and Olafson, N.Y., Cornell Vet., 41, 1951, pp. 237–239; Hansel, Olafson, and McEntee, N.Y., Cornell Vet., 43, 1953, pp. 311–324; Hansel, Olafson, and McEntee, N.Y., Jour. Dairy Sci., 37, 1954, p. 662; Sikes, Wise, and Bridges, Tenn., Jour. Amer. Vet. Med. Assoc., 121, 1952, pp. 337–344.

CHAPTER XX

CORN AND OAT GRAINS AND THEIR BY-PRODUCTS

I. THE CHARACTERISTICS OF THE CEREALS AS STOCK FEEDS

679. Importance of the cereal grains in stock feeding.—In the previous chapters emphasis has been placed on the importance for livestock of good roughage, including pasture, hay, dry fodder, and silage. However, for efficient livestock production, concentrates are usually needed in addition to good roughage. This is because forage alone is too low in digestible nutrients and net energy to meet the needs of stock for high production.

To secure the greatest profit from good dairy cows, it is generally necessary to feed them a liberal amount of concentrates in addition to plenty of high-quality roughage. Likewise, in order to produce the quality of meat desired by consumers, fattening cattle and lambs must usually receive considerable quantities of grain or other concentrates. Horses or mules cannot do much work on roughage alone. Swine and poultry must be fed chiefly on concentrates, because their digestive systems can make only limited use of forage.

The cereal grains and their by-products form by far the greater part of all the concentrates used for livestock in this country. Indeed, all classes of stock except poultry are frequently fed only farm-raised grain and roughage with the small amounts of protein or mineral supplements in addition that may be needed to balance their rations. The grains and by-products therefore merit first consideration among all the concentrates.

680. Nutritive characteristics of the grains.—The cereal grains are all high in starch and either low or relatively low in fiber. They are therefore rich in total digestible nutrients and net energy. In addition, nearly all the grains are highly palatable to stock, which is important with animals being fed for production. Rye is the only one of the common grains that is sometimes not well liked by stock.

Corn, wheat, and the grain sorghums lead in amount of total digestible nutrients and net energy, being closely followed by barley and rye. Oats, with their thick hulls, are higher in fiber and therefore lower in digestible nutrients.

Corn and rice are decidedly low in protein, and other grains are relatively low in protein. The proteins of the grains are also of poor quality, for they contain only small amounts of certain of the essential amino acids. (120) In feeding swine and poultry, efficient results cannot therefore be secured unless protein supplements of good quality are fed in addition to grain, so that sufficient amounts of these amino acids will be supplied.

It is fortunate indeed that for dairy cows, beef cattle, sheep and horses, legume hay will fully make good any deficiencies of the cereal grains in quality of protein and will also largely or even entirely balance the ration in amount of protein. (126) Even for swine, legume hay and especially legume pasture help to make good the deficiencies of the cereal grains in amount or quality of protein. (124)

The grains are not rich in phosphorus, but are slightly higher in this mineral nutrient than are the common hay crops, including both the legumes and grasses. (148) Corn and the grain sorghums are lower in phosphorus than oats, wheat, barley, or rye. Certain of the grain by-products, especially wheat bran and wheat middlings, are rich in phosphorus. On the other hand, corn gluten meal and brewers' grains do not contain much more phosphorus than the grains themselves.

All the grains are very low in cal-

cium, and this fact must be borne in mind in livestock feeding. (**146**) Corn is especially deficient in this respect.

None of the grains contains an appreciable amount of vitamin D. (**204**) With the exception of yellow corn, none of the grains supplies any significant amount of vitamin A value. (**197**) The grains are fairly rich in thiamine but are low in riboflavin. Wheat, barley, and the grain sorghums contain considerable niacin, but corn, oats, and rye are much lower in content of this vitamin. All the grains supply vitamin E in fair amounts.

CORN IS BY FAR OUR MOST IMPORTANT CROP

In acreage and in value Indian corn is the most important crop in the United States.

II. INDIAN CORN AND ITS BY-PRODUCTS

681. Importance of Indian corn for grain.—Indian corn (*Zea mays*), or maize, is by far the most important crop in the United States. Nearly one-quarter of our entire crop acreage each year grows corn, and of the entire crop, over 85 per cent is harvested for grain. Corn holds this position in our country because it surpasses all the other cereals in yield of both grain and forage, wherever it thrives.

Previous to the restrictions on corn acreage in the United States, about 90,000,000 acres of corn were grown annually for all purposes. During recent years the acreage has been reduced to about 80,000,000 acres. However, because of the general use of high-yielding hybrid corn and more adequate fertilization, the total production of corn grain has not been lessened.

For the 5-year period, 1949–1954, the average yield of corn grain in this country was 37.7 bushels per acre, a record high average yield, in comparison with 25.2 bushels for the 10-year period of 1924–1933. The high yield per acre during recent years was brought about by the general adoption of high-yielding hybrids, combined with improved fertilization and a succession of years of favorable weather.

The general requirements for the growth of corn and its use and value as a forage crop have already been discussed in Chapter XVII.

682. Composition and nutritive value of corn.—Corn grain is one of the best feeds for all classes of stock, when it is so fed as to take advantage of its great merits and to correct its deficiencies. It ranks far ahead of any of the other cereals in importance for livestock feeding in the United States, about 90 per cent of our huge corn crop being fed

to farm animals. The value and use of corn for each class of stock are discussed later in this chapter.

Corn ranks high among the grains in total digestible nutrients and net energy. The high content of total digestible nutrients (81.9 per cent for dent corn of No. 1 grade) is due to the following: Corn is very rich in nitrogen-free extract, which is nearly all starch; it is higher in fat than any of the other cereals except oats; and it is very low in fiber and therefore highly digestible. Another advantage of corn is that it is probably the most palatable of the cereals for most farm stock. A possible explanation for this is the high fat content, and the fact that on chewing, the kernels break into nutty particles which are more palatable than meal from wheat, for example.

The statement is sometimes made that corn is too "heating" to be fed to fattening animals as the only or the chief grain in warm weather. It is true that more care may be necessary to prevent such stock from going off feed in hot weather when fed all the corn they will eat. This is because corn is such a concentrated feed. However, even in hot weather, corn gives excellent results when fed as the only grain to fattening animals, if care is taken not to overfeed them.

Since it is so rich in starch, corn is naturally low in protein. Also, the protein of corn is of poor quality for nonruminants, because it is low in two of the essential amino acids—tryptophan and lysine.

Most of the varieties of hybrid dent corn now so widely grown in this country are apparently lower in protein than the varieties formerly raised. In the compilation of analyses published by the author in 1936, the average protein content of No. 2 dent corn was 9.4 per cent.[1] The figures for the average composition of dent corn given in Appendix Table I of this volume are based on nation-wide studies made during two seasons by the Committee on Feed Composition of the National Research Council of the composition of the leading hybrid varieties in the various states.[2]

In the first year, which was a good corn year, the average protein content of Grade No. 2 dent corn over the country was only 8.7 per cent. The following year, which was a year in which some corn did not mature so well, the average protein content on the same dry-matter basis (85 per cent dry matter) was a trifle higher, being 8.9 per cent.

This decrease in the protein content of our corn grain since the general adoption of hybrid varieties seems to be due to a combination of factors. Because of the high yield of hybrid corn, together with the heavier planting rates now commonly used, the available nitrogen supply in the soil is nearly exhausted before the corn matures, unless the crop is fertilized unusually liberally with nitrogen. Consequently, the protein content of the grain is reduced.[3] In addition, even when well fertilized with nitrogen, most of the hybrid varieties apparently tend to produce grain of somewhat lower protein content than did the old open-pollinated varieties formerly grown.[4]

Corn is extremely low in calcium, having but 0.02 per cent. This means that there is only 0.4 lb. of calcium in an entire ton of the grain. Corn also has less phosphorus than other common grains, No. 2 dent corn having an average of only 0.26 to 0.27 per cent.

It is pointed out in following paragraphs that yellow corn has considerable vitamin A value, while white corn has none. Both yellow and white corn lack vitamin D. Corn is fairly rich in thiamine, but it is lower than wheat or barley in niacin, and, like all the other grains, is low in riboflavin.

683. High-protein or high-fat corn. —Through long-continued inbreeding, plant breeders some years ago developed strains of corn in which the grain was much higher than normal in protein or in fat. However, the yield of these inbred strains was too low for them to be of practical importance. By utilizing high-protein inbred strains in the breeding of certain hybrid varieties, hybrids have been produced which are high in protein but also yield fairly well.

High-protein hybrids have been de-

veloped commercially that produce grain having 11 to 15 per cent protein when the crop is liberally fertilized with nitrogen. However, the yield of the present high-protein hybrids is generally so much lower than that of the best ordinary hybrids that their use has not become common.

Experiments have shown that in high-protein corn the chief increase is generally in zein, which lacks lysine and has very little tryptophan.[5] (117) The total protein of such corn is therefore lower than usual in these two essential amino acids. Consequently, in feeding high-protein corn to swine or poultry, this lack must be corrected by the use of protein supplements, such as fish meal, soybean oil meal, or blood meal, which have good supplies of these amino acids.[6]

The use for cattle or sheep of high-protein corn grain or silage made from such corn reduces the amount of protein supplement needed to balance the ration. However, this saving is not usually sufficient to offset the lower yield of the high-protein corn.[7]

684. Yellow corn has vitamin A value.—It has been shown in Chapter VII that yellow varieties of corn and varieties with yellow endosperm (the starchy part of the kernel) have considerable vitamin A value, because of the content of carotene and related pigments. (197) Yellow corn is therefore an important source of vitamin A in stock feeding. However, it has much less vitamin A value than green forage or even well-cured hay. Part of the yellow color in yellow corn is due to xanthophyll, which has no vitamin A value. White corn or other corn with white endosperm has practically no vitamin A value.

In general, deep yellow corn has a higher vitamin A value than light yellow varieties, although the vitamin value is not always proportional to the depth of yellow color. This is because the proportion of xanthophyll varies. On storage for 2 or more years, the vitamin A value of yellow corn sometimes decreases considerably, without any great change in color of the corn. (195)

The vitamin A value of red varieties or varieties with hulls of other colors will depend entirely on whether the endosperm is yellow or white. The gluten of yellow corn is richer than the rest of the kernel in vitamin value. Therefore corn gluten feed and corn gluten meal from yellow corn are richer than yellow corn in vitamin A value.

Whether or not yellow corn will have a higher value than white corn for stock feeding, will depend on whether the other feeds in the ration provide plenty of vitamin A value. In general, white corn is equal to yellow corn for all stock on green, actively-growing pasture and also for dairy cattle, beef cattle, sheep, or horses which are fed a reasonable amount of good-quality hay or silage.[8] For swine or poultry that are not on pasture, the difference in vitamin A value of yellow and white corn may make all the difference between profit and failure, unless care is taken to provide sufficient of the vitamin in other feeds.

For example, in 5 Wisconsin tests young pigs not on pasture were fed to market weights on either white corn or yellow corn, supplemented by tankage, skimmilk, or whey and linseed meal (all of which supply little or no vitamin A).[9] The pigs fed yellow corn made decidedly more rapid and economical gains than those fed white corn, and on white corn many pigs became runts or died because of the vitamin deficiency. On the other hand, for pigs on good pasture there was no difference in the value of the two kinds of corn, because green forage supplies an abundance of vitamin A value. Adding a small amount of leafy, well-cured legume hay to the ration entirely corrects the deficiency of vitamin A in white corn and in the small grains.

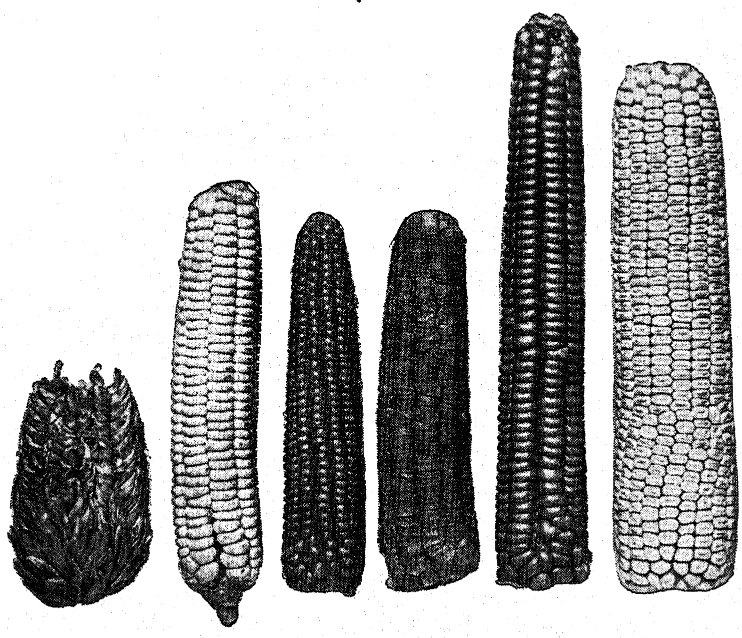
Yellow corn produces yellow color in the yolks of eggs and in the shanks, beak, and skin of fowls, while white corn does not. This is due partly to the carotene it contains, but chiefly to the xanthophyll. (14) Except for this difference, white corn is equal to yellow for poultry, if the ration otherwise supplies plenty of the vitamin.[10]

Previous to the discovery in 1920

that yellow corn has vitamin A value, only about one-half of the corn sold under Federal inspection on the large markets in this country was yellow. By 1942, 90 per cent of the corn on these markets was yellow. Because of the scarcity of white corn, it commanded a premium in price, as it is required for certain special uses, such as the manufacture of corn flakes.

is changed to tough, horny starch as they mature. Mature sweet corn has somewhat more protein, much more fat, and correspondingly less carbohydrates than dent corn.

Pop corn that is off-grade and unsuitable for popping may be used for feeding. It should be ground as the kernels are very hard. Pop corn is higher than dent corn in protein and fat.



EARS OF DIFFERENT TYPES OF CORN

From left to right: Pod corn, a primitive type; soft corn, an unimproved type having no horny starch; pop corn; sweet corn; flint corn; dent corn. (From Wisconsin Station.)

685. Types of corn.—*Dent corn* is the type generally raised in this country. *Flint corn* has about the same chemical composition and feeding value as dent corn, but the kernels are harder because the starchy portions are mostly horn-like and flinty. Since flint corn is harder, there may be more advantage in grinding it than in the case of dent corn. In 3 Ohio experiments shelled flint corn was worth 3 per cent less than dent corn when self fed to fattening pigs.[11]

Sweet corn is rarely fed to stock. Before hardening, the milky kernels of sweet corn have much glucose, which

Waxy corn, in which the starch is waxy and similar to tapioca starch, is grown to a limited extent because of the special qualities of the starch for food and technical uses. Though waxy corn was less palatable to pigs in Nebraska trials, it was fully equal to ordinary corn in feeding value.[12] It also equalled dent corn in value for chicks.[13]

686. Hybrid corn; hardness of kernels.—The kernels of some of the hybrid corn varieties are considerably harder than those of the old open-polinated varieties, and also most of the hybrids are lower in protein. Several experiments

have therefore been conducted to compare various hybrids with open-pollinated varieties which were formerly grown widely.[14] In some of the tests the hybrids have been fully equal to the older varieties for swine or for fattening cattle, but in other tests they have been worth slightly less per bushel. For example, in 7 Ohio experiments with growing and fattening pigs fed plenty of protein supplement, hybrid corn was worth 97 per cent as much, on the average, as open-pollinated varieties. Any such small difference in feeding value is much more than offset by the higher yield of hybrid corn adapted to the particular section.

If the hybrid corn is low in protein, obviously, a greater amount of protein supplement must be fed with it to balance the ration.

687. Storage of corn.—For safe storage in the fall in the usual types of corn cribs, ear corn should be sufficiently matured so that the kernels do not contain more than about 20 per cent of water. The cobs will then have a considerably higher percentage of water. Shelled corn stored in an ordinary bin may spoil in warm weather if it has more than 13 to 14 per cent of water. In cool weather it can be shipped without much risk of heating when it contains as much as 16 to 18 per cent of water, but such corn cannot be stored safely for any long period.

For satisfactory storage, ground corn must be thoroughly dry, containing not more than 12 to 13 per cent water, or else it is apt to mold or turn rancid. Even then it may gradually become sour; therefore corn should not be ground a long time before it is fed.

In the North corn is stored on the farm mostly as husked ear corn, but in the South the husks are left on, in order to protect the ears from weevils.

688. Grades of shelled corn; weight of corn.—Shelled corn is sold on the large markets according to the Federal corn grades. These are based on the percentage of water and also on the percentage of unsound kernels and foreign material. Since the feeding value depends, first of all, on the water content, separate averages are given in Appendix Table I for corn of the various grades.

According to the Federal grades, the percentage of water in corn must not exceed 14 per cent for Number 1; 15.5 per cent for Number 2; 17.5 per cent for Number 3; 20.0 per cent for Number 4; and 23.0 per cent for Number 5. Corn containing more than 23 per cent water, or which does not come up to the standards in other respects, must be sold as "Sample grade."

Seventy pounds of dry dent ear corn of good varieties yield 1 bushel, or 56 lbs., of shelled corn, but in early fall buyers frequently demand 75 to 80 lbs. or more, according to the estimated water content. Flint varieties have a somewhat smaller shelling percentage than dent corn.

689. Soft corn.—When corn is frosted before the grain matures, the ears contain too much water for ordinary storage. Such soft corn can best be utilized for stock feeding. The entire crop may be ensiled; it may be put in small, well-built shocks in the field until it is fed; or silage may be made from the snapped ear corn. Soft corn should be used up during the cold weather, as it will spoil when the weather becomes warm. Soft corn can be dried with heated air, for storage.

Soft corn that has not reached the dent stage is lower in nitrogen-free extract and fat than mature corn, and is therefore lower in energy value. However, it is higher in protein.

Soft corn, if not moldy, may be fed to all classes of stock.[15] It is well to accustom animals to it gradually, to avoid possible digestive disturbances. Experiments have shown that when soft corn is of good quality, the feeding value of the dry matter in it is about equal to that in mature corn. Of course, the value per acre is much lower, because of the reduced yield of dry matter from the immature crop. The gains of fattening cattle may be somewhat slower on soft corn than on mature corn, owing to a smaller consumption of dry matter.

Moldy soft corn had best be fed to cattle or swine, as it may be dangerous to horses and even to sheep, though sheep sometimes do well on it. When soft corn becomes moldy, it is worth considerably less, on the dry basis, than sound corn.

Snapped ear corn makes satisfactory silage, which may be fed as a substitute for other forms of corn grain to cattle or sheep.[16] It has not given good results in tests with pigs. The snapped corn must be chopped finely by running it through a silage cutter and should be tramped well in the silo. If the corn is past the milk stage, it is well to add approximately 40 gallons of water to each ton of ears. Chopped straw or corn stover, well wet down, should be used to cover the ear corn at the top of the silo, to prevent the waste of the more valuable feed. Flood-damaged ear corn may be similarly ensiled.

690. Forms in which corn is fed.—Corn grain is fed in the following different forms: ear corn, snapped corn, shelled corn, cracked corn, ground corn, corn-and-cob meal (ground ear corn), and ground snapped corn. Sometimes hogs or fattening lambs or cattle are turned into a ripe field of standing corn to harvest the crop. The relative values of the various ways of feeding corn to the different farm animals are discussed in articles which follow. The best form for any class of stock will depend primarily on how thoroughly the animals chew the grain when fed whole.

Ground corn is the term commonly used in this book for the entire ground grain from which the hulls or germs have not been removed. Ground corn is also called *corn chop* or *corn meal.* Very coarsely ground corn is called *cracked corn.*

When corn is ground for stock, medium-fine grinding is preferable to fine grinding, for such ground corn is more palatable, and also much less power and labor are required for the grinding. As has been mentioned previously, ground corn in any form does not keep so well in storage as shelled corn or ear corn.

Especially for poultry feeds, the fine siftings are often removed from cracked corn or coarsely-ground corn, and the product is then called *screened cracked corn, screened ground corn* or *screened corn chop.*

The fine siftings that are removed, with or without the light fragments of of the hulls, etc., are known as *corn feed meal.* This has about the same composition and value as ground corn, except it is slightly higher in protein and fat, but it is also somewhat higher in fiber.

Corn-and-cob meal, ground ear corn, and *ear corn chops* all mean the entire ground ear corn, including the cobs. The cobs usually form about 20 per cent of the weight of corn-and-cob meal. Because of the ground cobs, corn-and-cob meal is more bulky than ground corn.

On account of the rubbery nature of corn cobs, more power is needed to grind ear corn than shelled corn. However, it may cost less to grind the ears than to shell the corn and then grind it.

When the entire corn ears in the husks, or shucks, are ground, the product is called *ground snapped corn,* or *ear corn chops with husks.*

The use of corn-and-cob meal and ground snapped corn for the various classes of stock is discussed in the following articles.

691. Corn cobs.—Except when ear corn was ground into corn-and-cob meal, but little use was made of ground corn cobs for stock feeding until recently. Because of the great quantity of cobs available annually in this country, many experiments have been conducted during the past few years to find how ground corn cobs can be utilized for feeding ruminants.

Corn cobs have 32 per cent fiber and even for ruminants usually supply only 45.9 per cent of total digestible nutrients, which is a trifle more than in oat straw or cottonseed hulls. They have only 2.3 per cent of protein, and this is digested so poorly that they furnish no digestible protein. They are also very low in minerals, having but 0.04 per cent phosphorus. They do not supply carotene and are very low in other vitamins.

The experiments have shown that to enable ruminants to utilize ground corn cobs, the ration must be amply supplemented, or else the nutrients will not be provided to permit efficient digestion of the ground cobs by the rumen bacteria.[17] (45) The supplements needed are: (1) A plentiful supply of protein. This can be replaced partly by a protein

substitute, such as urea. (2) A source of readily available energy, such as molasses or ground grain. (3) Additional phosphorus and other minerals. (4) Unidentified factors needed by the rumen bacteria, which are furnished by high-quality roughage or by molasses.

Even when adequately supplemented, ground cobs are distinctly a roughage, and a low-grade roughage at that. However, ground cobs may be an economical roughage when available for not much more than the cost of hauling and grinding. They cannot replace corn grain or other feeds high in total digestible nutrients and net energy.

Most of the experiments to study the use of ground cobs have been with beef cattle, and cobs apparently have the most usefulness for them, especially as part of the ration for wintering young stock or beef cows. Data are limited concerning the value of ground cobs for dairy cows or sheep.

Swine or poultry can get little nourishment from corn cobs. Ground cobs should therefore not be added to their rations, except as ear corn is ground for swine to form corn-and-cob meal. (**703**)

Corn cobs must be ground fine enough so larger particles will not be refused. In grinding them with a hammer mill, a one-half or five-eighths inch screen should be used. As ground cobs are not palatable when fed separately, the supplement should be well mixed with them.

When ground cobs are high in moisture, considerable heating and molding will occur if they are stored longer than about 2 days in warm weather.

692. Ground corn cobs for beef cattle.—Experiments have shown that when properly supplemented, ground cobs can be used as the only roughage for wintering young beef cattle or beef cows. In Indiana trials calves have gained 1.0 to 1.5 lbs. a day when wintered on ground corn cobs and 3.5 lbs. per head daily of such a protein-rich supplement as Purdue Supplement A, described in Chapter XXVIII.[18] In these experiments ground cobs, fed as the only roughage, produced greater gains than did oat straw or cottonseed hulls, but not nearly such large gains as did corn silage similarly supplemented.

In Kansas trials calves made as good gains with properly supplemented ground cobs for the only roughage as with prairie hay.[19] However, more protein supplement was of course needed with the ground cobs. In Nebraska tests ground cobs satisfactorily replaced half the corn silage in well-balanced rations for wintering calves.[20]

Ground cobs, fed with 4.8 lbs. per head daily of a protein-rich supplemental mixture, were as satisfactory as grass hay for wintering beef cows in North Carolina trials.[21]

Ground corn cobs can be used to replace part of the corn grain in a ration for fattening cattle. The use of corn-and-cob meal, which contains about 20 per cent of cobs is discussed later. (**696**) When corn is high in price or the supply is limited, it may be economical to include more ground cobs in the concentrate mixture, especially in fattening cattle of the lower grades that are not carried to a high degree of fatness.

When twice as much ground cobs as are present in corn-and-cob meal have been included in rations for full-fed fattening cattle, the gains have usually been less rapid than when corn grain, without cobs, was used instead.[22] Also, the cattle do not reach as high a finish and bring a slightly lower price on a discriminating market. If pigs follow the fattening cattle, less pork is produced on high-corn-cob rations. Considering these factors and also the greater amount of protein supplement needed with added ground cobs, they have been worth about one-half as much per ton as corn grain when thus used.

In an Iowa experiment fattening cattle made excellent gains when self-fed only a mixture of corn-and-cob meal, ground cobs, soybean oil meal, cane molasses, urea, minerals, stilbestrol, and vitamin A supplement.[23]

693. Ground corn cobs for dairy cattle and sheep.—Indiana and Virginia experiments show that ground cobs are very unsatisfactory as the only rough-

age for dairy cows, even when well supplemented, but that the milk production is only slightly decreased when ground cobs are substituted for half of the hay usually fed.[24] In another Virginia trial the milk production was only slightly decreased when 20 per cent of ground cobs was added to a concentrate mixture that contained one-half corn-and-cob meal.[25]

A mixture of ground cobs, soybean oil meal, bone meal, trace minerals, and vitamin A-D supplement satisfactorily replaced bromegrass hay for dairy heifers in an Illinois trial, but the hay was cheaper.[26] In Kentucky experiments ground cobs, well supplemented, were equal to cottonseed hulls as the roughage for dairy heifers.[27]

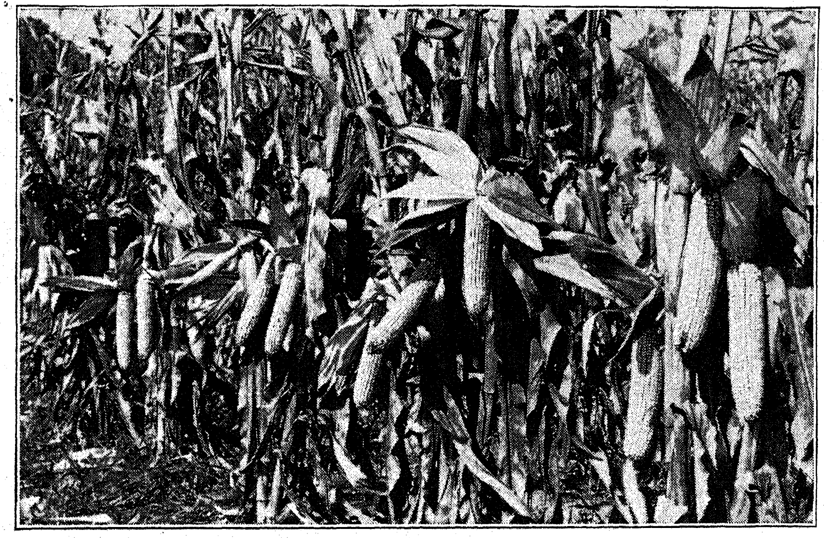
Ground corn cobs had no appreciable value as part of the ration for wintering breeding ewes in 3 Ohio experiments, and in an Indiana trial less satisfactory results were secured with ground cobs, properly supplemented, as the only roughage than with corn silage or grass silage.[28]

694. Corn for dairy cattle.—Corn is an excellent feed for dairy cows or other dairy cattle, when fed with feeds that make good its deficiencies. Since corn is a heavy feed, most dairymen prefer to use it as only part of the concentrate mixture, mixing ground corn with such bulkier feeds as wheat bran or ground oats. Nevertheless, for cows of average production, a mixture consisting only of ground corn and protein supplement can be used satisfactorily. (**1016**, **1071**)

A West Virginia test shows that, contrary to the beliefs of some, a concentrate mixture consisting chiefly of corn does not increase the trouble from mastitis in dairy cows.[29]

Good legume hay, especially alfalfa, makes good the deficiency of corn in protein. Therefore, for average cows such a mixture as one-half ground corn and one-half ground oats, without protein supplement, is satisfactory, if half the roughage, on the dry basis, is alfalfa.

On the other hand, the results are very unsatisfactory when corn or such a mixture as corn and oats is fed without a protein supplement to cows receiving little or no legume roughage. For example, in an Illinois experiment one group of cows was fed on corn grain as the only concentrate, with timothy hay,



A FINE FIELD OF DENT CORN

The husks have been stripped back to show the ears.

corn silage, and a small amount of clover hay for roughage.[30] Another group was fed a well-balanced ration of clover hay, corn silage, and a mixture of ground corn and gluten feed. The cows fed the balanced ration produced 47 per cent more milk and 39 per cent more fat than those fed the same weight of concentrates and roughages in the unbalanced ration.

Experiments have proved conclusively that it pays to grind shelled corn or ear corn for dairy cows.[31] If cows are fed whole shelled corn, as much as 18 to 35 per cent of the grain passes through the digestive tract unchewed and with but little digestion of the nutrients in these whole kernels. The corn should be ground to only a medium degree of fineness, for extremely fine grinding is unnecessary and unduly expensive. Merely cracking it is not sufficient to ensure thorough digestion.[32]

Shelled corn is chewed thoroughly by calves up to 8 or 9 months of age and therefore it is unnecessary to grind it for them.[33] Heifers also chew corn much more thoroughly than do cows. In Michigan experiments only 6 per cent of the shelled corn was not masticated by calves and 11 per cent by heifers, in comparison with 23 per cent by cows.[34]

When other bulky concentrates are not included in the ration, 100 lbs. of corn-and-cob meal, including the cobs, may equal or approach in value an equal weight of ground corn. On the other hand, if the concentrate mixture is already reasonably bulky, corn-and-cob meal is apparently worth no more than the amount of corn grain it actually contains, fed as ground corn.[35] If the cost of grinding ear corn to corn-and-cob meal is less than the cost of shelling it and then grinding the shelled corn, it is economical to use corn-and-cob meal, even if there are other bulky feeds in the concentrate mixture.

In 3 Ohio trials simple concentrate mixtures were compared, which consisted only of either corn-and-cob meal or ground shelled corn supplemented by soybean oil meal and minerals.[36] In each of the tests the milk production was a trifle less on the corn-and-cob meal mixture, but the average difference was less than 2 per cent. Corn-and-cob meal was the more economical form for feeding, because of the lower cost of preparation.

695. Corn for beef cattle.—Corn is by far the most important concentrate for fattening cattle in the United States. It excels not only because of its richness in total digestible nutrients, but also because no other grain is so palatable to cattle. It is therefore taken as the standard with which other grains are compared.

Corn is likewise very satisfactory for breeding cattle, if it is properly fed. Breeding stock should not be fed so much corn that they become too fat. Also, care must be taken to provide plenty of protein and minerals, and some legume hay should be included in the ration, if available.

When beef cattle are on good pasture or when they are fed roughage of good quality furnishing sufficient vitamin A value, there will be no difference in the value of yellow corn and white corn for them. (684)

Whether to feed fattening cattle all the corn or other grain they will eat or to limit the amount of grain, is a problem of the utmost importance. This is discussed in Chapter XXVIII.

696. Preparation of corn for beef cattle.—*Shelled corn* is a common form for feeding corn to fattening cattle that are followed by pigs to consume the kernels that escape chewing and digestion. Experiments have shown that in such cases there is not generally sufficient saving through grinding corn to warrant the expense.[37] On the other hand, it pays to grind shelled corn or ear corn for cattle over 8 or 9 months of age, if they are not followed by pigs.

Coarse or medium-fine grinding of corn is preferable to fine grinding, for such grain is more palatable and also less apt to cause heavily fed fattening cattle to go off feed. Ear corn should be ground fine enough so that the cattle will eat the fragments of cobs. Up to 8 or 9 months of age, calves chew corn and oats so thoroughly that it does not pay to grind these grains for them.

Cattle that are being fitted for show or sale are generally fed *ground corn*, because it usually produces a trifle more rapid gains than shelled corn or ear corn. For the same reason, it pays to grind corn when one wishes to force cattle to make maximum gains, so as to be ready for market before an expected decline in the price of fat cattle.

Some years ago *broken ear corn* was the most common form for feeding fattening cattle in the corn belt. However, with the general availability of electric power, ear corn is now generally ground into *corn-and-cob meal*, as less labor is required than in preparing broken ear corn.

If pigs do not follow fattening cattle, *corn-and-cob meal* is an economical form in which to feed corn. The daily gain is apt to be a little less than on ground corn, but the ground cobs in corn-and-cob meal save some of the other roughage. It was concluded from Ohio experiments that each 100 lbs. of corn cobs in corn-and-cob meal was worth about as much as 50 lbs. of ground corn.[38] In Indiana trials with beef calves being wintered, the gain was slightly less on corn-and-cob meal than on ground shelled corn, and 100 lbs. of corn-and-cob meal was equal in value to 90 lbs. ground corn minus 40 lbs. hay.[39]

Because of the greater bulk of corn-and-cob meal, it is easier to get cattle on a full feed of grain without digestive disturbances. Corn-and-cob meal is also a safer feed for an inexperienced feeder to use than shelled corn or ground shelled corn.

Corn-and-cob meal will even produce good gains on fattening cattle without the feeding of any other roughage than is furnished by the corn cobs present, if a special supplement is fed that makes good the deficiencies in corn cobs and corn grain that have been previously stated.[40] (691)

Formerly broken ear corn was a popular form for feeding farm-raised corn from fall until spring to fattening cattle that were followed by pigs.[41] In the summer, when the ears became dry and hard, shelled corn or ground corn gave better results. Ear corn is broken by running it through a silage cutter or other machine. It can also be sliced by means of a corn knife, or broken over the edge of the manger.

Snapped corn (ear corn with adhering husks, which has been snapped from the corn stalks) is often fed to beef cattle during fall and early winter. It is better adapted to yearlings or 2-year-olds than to calves.[42] Even for the older cattle, it had best be replaced by broken ear corn or shelled corn during the latter part of the fattening period.

Corn is sometimes fed to fattening cattle in the form of *ground snapped corn* (ear corn ground with the shucks or husks). In 6 Tennessee experiments with calves fed for baby beef, the gains were a little less rapid and the net return per steer somewhat lower on ground snapped corn than on shelled corn or ground shelled corn.[43] In 6 Georgia trials older fattening cattle gained 2.13 lbs. per head daily on ground snapped corn and 2.40 lbs. on cracked shelled corn.[44] The selling price was slightly lower for the cattle fed ground snapped corn, and 100 lbs. of ground snapped corn was about equal in value to 75 lbs. of cracked shelled corn.

697. "Cattling down" corn.—Particularly in the corn belt, fattening cattle are sometimes turned into standing corn to harvest the crop. Cattle that are at least 2 years old are much better for this purpose than younger animals. The cattle should always be brought to a full feed of grain before they are turned into the field, or they may overeat and suffer from indigestion. In using this method, it is important to feed sufficient protein supplement to balance the ration, and to have about twice as many pigs following the cattle as would be needed in dry-lot feeding. In the southern states standing, thickly-planted, mature corn is sometimes used for winter pasture for beef cows.[45]

698. Corn for sheep.—In all the corn-growing districts of this country, corn is the grain most commonly fed to fattening lambs. It is also widely used as part of the concentrates for breeding ewes and young lambs.

A ration of only corn grain and either alfalfa or clover hay is excellent

for fattening lambs, for they eat enough of the legume hay to supply sufficient protein to produce good gains. As is shown in Chapter XXX, the gains will usually be a trifle more rapid when the lambs are fed in addition a small amount of such a supplement as linseed meal or cottonseed meal. However, the addition of the supplement will generally be uneconomical.

Numerous experiments have proved that fattening lambs will not make rapid or economical gains when they are fed only corn and non-legume roughage, without a protein supplement. For example, in 7 tests lambs fed corn with timothy or prairie hay, without any supplement, gained an average of only 0.19 lb. per head daily, in comparison with 0.32 lb. for others fed corn with clover or alfalfa hay.[46] The lambs on the unbalanced ration required 46 per cent more corn and 15 per cent more hay for each 100 lbs. gain than those fed the balanced ration of corn and legume hay.

When fed in a properly-balanced ration, corn can be used successfully as the only grain for breeding ewes in winter, provided the allowance is limited so the ewes do not become too fat. However, shepherds generally prefer more bulky mixtures, such as are mentioned in Chapter XXXI.

In the corn belt, corn is extensively fed as the only grain to fattening lambs, after they are safely on feed. For fattening lambs which are hand-fed it gives excellent results when thus used, if it is properly balanced by feeds supplying plenty of good-quality protein and of calcium. When lambs are self-fed corn, some bulky feed like chopped hay or oats should be mixed with it to lessen digestive troubles, which may otherwise cause serious death losses.

Even in hand-feeding fattening lambs, it may also be safer to mix bulky feeds with corn, if they are being forced as rapidly as possible on all the grain they can be induced to eat. In these cases such a combination as 2 to 3 parts corn and 1 part oats, by weight, is excellent.

699. Feeding corn in various forms to sheep.—Corn grain is usually fed to sheep and lambs in the form of shelled corn or as ear corn. Experiments have shown clearly that there is usually no advantage in grinding shelled corn or in grinding ear corn for sheep, with the following exceptions:[47] (1) For sheep with poor teeth, (2) for young lambs up to 5 or 6 weeks of age, and (3) when fattening lambs are being self-fed such a mixture as corn grain and chopped hay, or even when they are being hand-fed all of such a mixture that they can be induced to eat.

Usually hand-fed lambs will make slightly more rapid and economical gains on shelled corn than on ground corn. Likewise, ear corn or broken ear corn has given as good or even better results than corn-and-cob meal. Corn ground coarsely is preferable to fine meal for sheep or lambs.

For fattening lambs ear corn or broken ear corn produced just as rapid gains, on the average, in 9 trials as shelled corn, when each was fed as the only grain.[48] Also, the cost of feed per 100 lbs. gain was slightly less for the lambs fed ear corn.

Sometimes fattening lambs are fed shock corn, ears and all, usually being given a small amount of shelled corn or other grain at first, until they learn to husk the corn ears.[49] The lambs may not gain quite so rapidly when fattened by this method and a little more corn may be required per 100 lbs. gain, but the method saves labor, compared with the feeding of corn in other forms.

Both ear corn and shock corn are better suited for feeding on a thick sod than in a dry lot or barn, for they may be scattered on the sod so that each lamb will have an equal chance to feed, and little will be wasted. In the lot or barn, lambs are apt to drop the ears where they become soiled, or to bunch them up in the trough so that each lamb does not get its share.

700. Fattening lambs in the corn field.—In some districts many farmers fatten western lambs in the corn field. This is called "lambing down corn." When conditions are favorable, lambs fattened in the corn field with supplemental feed make nearly as rapid

gains as those fed corn and legume hay in dry lot, but the death losses are apt to be higher.[50] In northern Colorado, such heavy death losses occurred from "overeating disease" that the practice was abandoned.

For lambing down, such supplemental crops as rape or soybeans should be grown in the corn. The lambs will usually clean up this forage long before they finish the corn. They should then be provided with good, palatable legume hay, so they will eat plenty of roughage. The best results are secured when 0.15 lb. per head daily of protein supplement is also fed from the start.

The lambs should have plenty of feed available without traveling too far, and they should have shelter from bad storms. It is the best plan to divide a large field into suitable areas by hurdles or by temporary woven-wire fencing. The lambs should be strong and healthy and should have dense fleeces which will shed water well. They should be accustomed to the corn gradually, by giving them a feed of hay in the morning the first few days before turning them on the field. At first the lambs will clean up the other vegetation in the corn field, including most of the weeds. Then they will begin eating the corn leaves and finally will learn how to husk out the corn ears and eat the grain from the cobs.

Plenty of hay and other feed should be available for feeding in bad weather or if the lambs clean up the corn field before they are fat. Severe financial losses will be incurred if one is forced to dump half-fat lambs on the market. The lambs should be inspected daily to see that all are thriving. Muddy fields are hard on their feet, as the mud cakes between their toes.

701. Corn for horses and mules.—Next to oats, corn is the grain most commonly fed to horses and mules in the United States. Several experiments have shown clearly that if work horses or mules are fed legume hay or mixed hay containing at least one-third legumes, corn is satisfactory as the only concentrate. For example, in a Missouri test mules fed shelled corn and mixed clover-and-timothy hay maintained their weights slightly better than those fed oats and hay.[51] This was in spite of the fact that each mule that was fed corn received 145 lbs. less grain and 75 lbs. less hay a year than did the mules fed oats. In this experiment there was a saving of 21 per cent of the cost of feed for the corn-fed mules.

As corn is a heavy, highly-concentrated feed, care must be taken not to feed more than is needed. It takes about 15 per cent less corn than oats to keep work horses in condition, when the ration is properly balanced in protein.

Although work horses and mules need much less protein than do dairy cows or fattening cattle or lambs, corn grain and ordinary grass hay make a ration too low in protein for the best results.[52] Therefore when corn is fed as the only grain with such roughage, a small amount of protein supplement should be added to balance the ration. This will usually save more than enough feed to be profitable, and it will also keep the animals in better condition and spirit.

If grass hay is cut reasonably early, so that it has a fair amount of protein, such a concentrate mixture as 900 lbs. of corn and 100 lbs. of oats will be satisfactory for mature work horses or mules.

Ear corn or shelled corn are the best forms of corn for feeding to horses or mules, unless their teeth are in poor condition. Grinding the grain does not make a sufficient saving of feed to justify the expense. Ear corn is preferable to shelled corn, for it keeps better, and horses eat it more slowly and chew it more thoroughly. If corn is ground for horses with poor teeth, it should be cracked or ground coarsely, for fine meal forms a mass in the stomach which is difficult to digest and may even cause colic. Corn-and-cob meal is better for horses than ground shelled corn, since it is more bulky. A slightly smaller weight of corn-and-cob meal than of oats is needed to keep work stock in condition, because oats are a little lower in total digestible nutrients.

702. Corn for swine.—Corn is the most common swine feed in the chief pork-producing districts of the United States. Indeed, it is estimated that hogs usually consume almost one-half of the total corn crop produced in this country. It is unsurpassed for growing and fattening pigs, and is therefore commonly taken as the standard with which other

grains are compared. Corn is also entirely satisfactory for brood sows and other breeding stock, when its deficiencies in protein, minerals, and vitamins are corrected, and when the amount of corn is limited so that they will not get too fat.

Excellent protein-rich pasture, such as alfalfa, clover, or rape, greatly reduces the amount of protein supplement needed to balance corn. As shown in Chapter XXXIV, it may not pay to feed any protein supplement at all to growing and fattening pigs on such pasture after they reach a weight of 100 to 125 lbs. For swine not on pasture, good-quality legume hay also helps to make good the protein deficiencies of corn. Indeed, pregnant mature brood sows can be wintered satisfactorily on nothing but corn grain, plenty of first-class legume hay, and minerals.

Experiments proved many years ago the folly of feeding corn alone or corn plus minerals to pigs not on pasture. For example, in 7 experiments with pigs averaging 69 lbs. in weight at the start, those fed corn without any protein supplement or pasture gained only half as rapidly as others fed corn and tankage, and many became stunted.[53] Each 100 lbs. of tankage fed to balance the ration saved 607 lbs. of corn. Other good protein supplements would have had a similar high value in balancing the ration.

Merely supplementing corn grain with a mineral mixture that supplies additional calcium and phosphorus, does not greatly improve the ration for pigs not on good pasture.[54] In order to produce satisfactory results, corn must be supplemented with good-quality protein, as well as with calcium and phosphorus.

Corn alone is just as unsatisfactory for pregnant sows as it is for young pigs, as is pointed out in Chapter XXXV. On the other hand, excellent results are secured with corn as the chief feed for brood sows, if the ration is properly balanced and if the allowance of corn is restricted so that the sows do not become too fat.

When white corn is used for swine feeding, care must be taken to provide plenty of vitamin A value in the other feeds in the ration.

703. Forms in which to feed corn to swine.—Corn is most commonly fed to swine in this country in the form of ear corn or as shelled corn. Numerous experiments have shown that for pigs up to the usual market weights, grinding corn does not make enough saving to warrant the expense. Ear corn usually produces as economical results as shelled corn. Sometimes pigs will make a trifle less rapid gain on ear corn than on shelled corn but will require no more actual corn grain per 100 lbs. gain.[55]

When pigs are self-fed shelled corn, they chew it even more thoroughly than when hand-fed, apparently because there is not the rush and competition among the pigs in getting their shares. In Indiana, Minnesota, and Wisconsin experiments in which pigs were grown and fattened to usual market weights on self-fed shelled corn or ground corn with good protein supplements, there was no saving whatsoever by grinding the corn.[56] The hardness of the corn did not seem to make any difference in the results of these tests, as the corn was rather hard hybrid corn in some cases.

In earlier experiments in which pigs were hand-fed, there was little or no saving through grinding corn for pigs until they reached a weight of about 150 lbs.[57] From then up to usual market weights, the saving was not usually more than 6 or 7 per cent. Soaking corn that has become very hard through storage will increase its value nearly as much as grinding it.

For feeding to brood sows, ear corn and shelled corn are the most economical forms.[58] If the sows do not chew all the kernels, they will be commonly sorted out of the droppings and thus finally utilized, for brood sows are not generally fed all the grain they will eat.

When shelled corn is ground for pigs, it should be ground to a medium degree of fineness. Pennsylvania and Wisconsin tests show that grinding to a fine meal does not increase the value of the grain over medium grinding, and the cost of labor and power is much

greater.[59] However, medium-fine grinding is preferable to merely cracking the grain.

In most of the experiments in which ear corn or shelled corn has been compared with corn-and-cob meal, the corn-and-cob meal has been less economical.[60] This is because pigs cannot digest the cobs to any appreciable extent, even when ground. If ear corn is ground for self-feeding, it must be ground fine enough to avoid clogging the self feeder.

In Georgia experiments ground snapped corn, including the husks, produced decidedly less rapid and economical gains than cracked shelled corn.[61]

704. Hogging down corn.—In some sections many farmers turn pigs into standing corn to harvest the crop. Numerous experiments have proved that this is an economical method of fattening pigs, if one does not wish to market them early, before the price drops in the fall and thus before the new corn crop is ready.[62] When corn is properly hogged down, pigs generally make fully as rapid gains as those fed corn and a good supplement in a dry lot. Also, they require no more feed per 100 lbs. gain. In addition, hogging down corn saves labor, conserves fertility, and provides the pigs with a fresh field which is free from parasites.

Experiments have shown that it is advisable to grow some protein-rich supplemental crop, such as soybeans or rape, with the corn for hogging down, or else to allow the pigs access to good pasture. This helps to balance the ration. The pigs should be fed 0.2 to 0.3 lb. per head daily of tankage or an equivalent amount of some other efficient protein supplement, unless protein supplements are unusually high in price. Somewhat more protein supplement is needed if no supplemental crop is grown in the corn. If no protein supplement is fed, it is very important to let the pigs have access to a mineral mixture supplying calcium and phosphorus.

Spring shotes, well grown on pasture and weighing 75 to 130 lbs. at the start, are best for hogging down. Lighter pigs may be used, if a few heavy hogs are put with them to break down the corn. Breeding stock should not be used to hog down corn, as they will get too fat. However, brood sows and their pigs can be turned into the field after the fattened pigs have been removed, to clean up what little corn is left.

Confining the pigs by a temporary fence to an area of the corn field that they can clean up in 2 or 3 weeks may reduce the wastage of corn. However, it adds to the expense and may not be advisable, except with heavy hogs and in very wet seasons.

Corn should not be hogged down until it has reached the glazing stage, because of the great storage of nutrients which occurs up to this time. Owing to the lower yield, it is doubtful whether it is advisable to grow very early varieties, so as to have the crop ready sooner.

In the corn belt the crops most commonly grown in corn for hogging down are soybeans or rape. Soybeans have generally been slightly superior to rape, and they also add nitrogen to the soil, if properly inoculated. Soybeans are planted with the corn at regular planting time, while rape is usually seeded at the last cultivation. In the South, cowpeas are often grown with corn for hogging down, or corn and peanuts are planted in alternate rows.

The area of corn needed for a given number of pigs will depend on the estimated yield. When a protein supplement is fed in addition to the corn, about a bushel of corn a day will be eaten during the hogging-down period by 9 or 10 pigs weighing 75 to 100 lbs. at the start, or by 5 or 6 pigs weighing 150 to 200 lbs.

705. Corn for poultry.—Corn is the chief grain fed to poultry in the United States, and it is unexcelled for this purpose when properly used. While corn is the most common ingredient in poultry rations, it is not essential and can be replaced satisfactorily by other grains. When corn forms a large part of the ration for poultry, it is very important to bear in mind that it is lower than wheat, barley, or oats in protein and also in calcium and phosphorus. Also, the protein in corn is of somewhat poorer quality than in these grains.

When white corn is fed, it supplies no vitamin A value. Yellow corn produces yellow color in the shanks, skin, and body fat and in the yolks of eggs, while white corn does not.

Where grain is fed separately to grown chickens, either as scratch grain or in a hopper, there is little or no advantage in cracking corn, except to force the birds to take more exercise. For use in the mash, corn should be ground, but not too fine, and it should be cracked or ground for chicks. Ear corn is not well suited for poultry. In 3 Ohio experiments corn-and-cob meal ground medium fine was a satisfactory substitute for ground corn in the mash for laying hens or for chicks.[63] With corn-and-cob meal there was a tendency for less feather picking and cannibalism of the layers, though the egg production was slightly lower.

When care is taken to balance the ration properly, corn can satisfactorily form a large part of it. For example, rations containing three-fourths corn have given good results with laying hens and also with chicks.[64] Under usual conditions, however, it is best to include wheat, oats, or other grains in the ration.[65]

Because of its high net-energy value, corn is one of the best feeds for use in rations for broilers and fattening poultry. A large percentage of corn is therefore included in most of the high-energy mashes for broilers. Corn-and-cob meal is not suitable for use in high-energy poultry mashes, because it has much more fiber than does ground corn.

706. Composition of the parts of the corn kernel.—Before discussing the value of the various corn by-products, let us consider the composition of the different parts of the corn kernel.[66] The starchy portion, or endosperm, which forms nearly three-fourths of the kernel, consists mostly of starch and has less than 10 per cent protein and only a trace of fat and minerals.

The hull and tip cap are also composed largely of carbohydrates, though containing less starch and about 15 per cent fiber. The horn-like gluten layer, just under the hull, contains about 22 per cent protein, and the germ carries nearly as much protein and about 35 per cent fat or oil.

707. Hominy feed; degerminated corn meal.—In the usual method of manufacturing corn meal for human use and also in making hominy and hominy grits, the germs and hulls are removed from the corn meal, along with fine siftings from the starchy portions. The *degerminated corn meal* thus produced has a more attractive appearance than the entire ground grain and also keeps much better in storage. However, it contains less protein and fat and therefore is of slightly lower value for stock feeding.

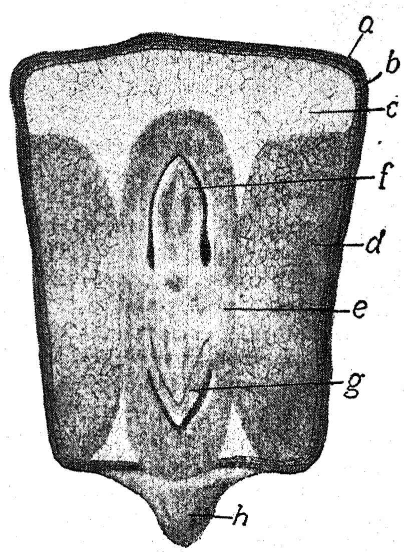


Diagram of a Kernel of Dent Corn

A, hull; b, hornlike gluten; c, floury starch; d, horny starch; e, embryo, or germ; f, embryo stem; g, embryo root; h, tip cap.

Hominy feed (also called hominy meal or hominy chop) is the by-product obtained in this dry-milling process. It consists of a mixture of the corn bran, the corn germs (with or without the removal of part of the fat), and a part of the starchy portion of the kernels.

Hominy feed resembles ground corn in composition and is about equal to it in feeding value for the various classes of stock. It is usually slightly higher than corn in protein, and it contains more fiber than corn and therefore is somewhat more bulky. Unless part of the fat has been removed from the germs, hominy feed will be considerably richer than

corn in fat and will furnish a slightly greater amount of total digestible nutrients.

According to the regulations of the Association of American Feed Control officials, hominy feed should not contain less than 5 per cent of fat.[67] Most samples of hominy feed analyzed by the state feed control laboratories conform to this regulation. These have an average fat content of 6.5 per cent. A few samples fell below the limit, having an average of only 4.6 per cent fat.

708. Value and use of hominy feed.—Hominy feed, often called merely "hominy," is a popular dairy feed. In Pennsylvania experiments hominy feed was practically equal in value to ground corn for dairy cows.[68]

In experiments with fattening cattle the value of hominy feed per ton has ranged from 90 to 100 per cent of that of corn.[69] For fattening lambs hominy feed has been about equal to shelled corn in value per ton.[70] Hominy feed is also a good substitute for corn in feeding horses.[71]

Hominy feed is a satisfactory substitute for corn in swine feeding, except for the fact that hominy feed which has the usual amount of fat tends to produce soft pork. In 23 experiments pigs fed hominy feed with tankage, meat scrap, or an efficient protein supplemental mixture gained 0.1 lb. less per head daily than others fed corn and the same supplements.[72] A trifle more hominy feed than corn was required for 100 lbs. gain, but on account of the somewhat higher protein content of hominy feed, a little less protein supplement was needed. With feeds at usual prices, hominy feed was nearly equal to corn in value, so far as economy of gains was concerned.

In Indiana experiments it was found, however, that if hominy feed having 6.5 per cent fat formed more than half of the ration, the carcasses of hogs tended to be soft.[73] Hominy feed of a low fat content did not have this effect, but its feeding value was appreciably less than that of corn.

Hominy feed is fully equal to corn in poultry rations. In Michigan experiments with broilers and with laying hens the value was even slighty higher than that of corn.[74]

709. Starch and glucose by-products.—In the manufacture of starch and glucose from corn by the wet-milling process, the grain is first softened by soaking in warm water to which sulfurous acid has been added to prevent fermentation. Next, the corn kernels are torn apart in special mills to free the germs. The material is then mixed with water and passed into tanks. Here the germs, which are lighter because of their high fat content, rise to the surface and are removed. The residue is finely ground and the hulls, or bran, separated by cloth sieves.

The liquid which remains contains the starch, the gluten, and very fine particles of fiber. The starch is separated either by centrifugal separators, which are somewhat like the cream separators used for milk, or by an older process in which it settles down in long, inclined troughs. The gluten is then removed from the water by filter presses, and dried. The starch is dried for sale as starch, or is treated with weakly-acidulated water under pressure to convert the starch into sugar, in making corn syrup and similar products. The steep water in which the corn is soaked is condensed by evaporation to recover the soluble nutrients removed from the grain in the soaking process. This residue is called "corn solubles."

In this process the following by-products are obtained: (1) The germs, from which most of the oil is later removed; (2) the bran; (3) the gluten; and (4) the corn solubles. The corn bran is not usually marketed as such, but goes into the gluten feed. The corn solubles may go into the gluten feed or may be used for other purposes, especially in the production of yeast or of penicillin. The protein in corn solubles is of low quality for non-ruminants.[75]

710. Corn gluten feed.—Corn gluten feed, usually called simply "gluten feed," consists of corn gluten meal and corn bran, with or without corn solubles. It may also include part of the corn oil

meal. Usually the manufacturers include just enough corn gluten meal in their corn gluten feed to meet safely a guarantee of 25 per cent protein or some lower percentage. They then sell separately the corn gluten meal in excess of the amount needed to produce the standardized corn gluten feed.

Corn gluten feed of the usual grades supplies about 70 per cent as much digestible protein as linseed meal, and is nearly equal to linseed meal in content of total digestible nutrients. The protein in gluten feed is not of good quality, and therefore gluten feed should not be used as the chief protein supplement for swine or poultry. Gluten feed is not quite so palatable as corn, oats, or wheat bran. It should therefore usually be mixed with such well-liked feeds.

The amount of phosphorus in corn gluten feed will depend on whether or not the corn solubles have been included in it. The average phosphorus content is 0.80 per cent, but it will be considerably lower if the corn solubles are not present. Because of the lime used in neutralizing the corn solubles, gluten feed usually contains more calcium than corn or the other grains.

Gluten feed made from yellow corn, as is usually the case, has a considerably higher vitamin A value than does yellow corn. The color of the gluten feed will show the kind of corn used.

Sometimes molasses is added to corn gluten feed to form *sweetened corn gluten feed.*

711. Gluten feed for dairy cattle.—Gluten feed is used chiefly for feeding dairy cows and is one of the most common protein-rich feeds for this purpose. Though gluten feed is best used as one of the ingredients in dairy concentrate mixtures, it has been fed with satisfactory results to dairy cows as the only or the chief concentrate.

In 5 New York experiments a simple mixture consisting only of corn gluten feed, corn gluten meal, ground corn, and ground oats, with or without molasses, gave as good results, when fed to high-producing dairy cows receiving very little legume roughage, as did a concentrate mixture having much more variety.[76] In another New York trial, when gluten feed formed one-half the concentrate mixture for dairy cows, the results were just as satisfactory as when a smaller proportion was fed.[77] Contrary to statements sometimes made, there is no scientific evidence that a large proportion of gluten feed increases mastitis in dairy cows.

In an Indiana experiment gluten feed was as satisfactory as linseed meal when fed as the only protein supplement to a ration of ground corn, corn silage, and legume hay.[78] Because of the lower protein content of gluten feed, it was necessary to use a larger proportion to balance the ration than in the case of linseed meal.

712. Gluten feed for other stock.—Gluten feed is a fairly satisfactory protein supplement for beef cattle, sheep, or horses. However, it has been inferior to linseed meal or cottonseed meal in the few experiments conducted with fattening cattle or fattening lambs.[79]

Occasionally, gluten feed is lower in price than corn grain. It may then be used as a partial or even a complete substitute for corn for fattening lambs or cattle. Thus fed to fattening lambs, gluten feed was worth only 86 per cent as much as corn per ton in Iowa trials.[80]

Gluten feed is not commonly fed to swine, as it is worth more for feeding to cattle. Because of the poor quality of protein in gluten feed, it is not satisfactory as the chief protein supplement in swine rations, even for pigs on pasture.[81] Gluten feed is rather bulky for swine, and it is not very palatable to them, although they will readily eat a mixture containing 10 to 15 per cent gluten feed. In general, gluten feed is not an economical addition to rations for swine unless the price per ton is less than that of corn or other grain.[82]

Gluten feed is not usually fed to poultry, but it can satisfactorily form about 10 per cent of the ration, replacing part of the other protein supplements.[83]

713. Corn gluten meal.—Corn gluten meal, commonly called "gluten

meal," consists chiefly of the corn gluten separated in the wet-milling process of starch manufacture, with practically none of the hull fragments. It may or may not include corn solubles and may occasionally contain some corn oil meal.

Gluten meal usually has more than 40 per cent protein, averaging 43.2 per cent. It has only 2.3 per cent fat, on the average, and is low in fiber. Gluten meal supplies nearly as much digestible protein as soybean oil meal, but the protein is not of high quality. Therefore gluten meal should not be used as the chief protein supplement for swine or poultry, but should be used with feeds which make good the deficiencies of corn protein.

Gluten meal is a heavy, concentrated feed and is higher than soybean oil meal in percentage of total digestible nutrients, averaging 79.7 per cent. When made chiefly from yellow corn, as is generally the case, gluten meal is even higher than gluten feed in vitamin A value, but it is much lower in calcium and phosphorus. Gluten meal is also very low in riboflavin.

714. Gluten meal for dairy cattle.—Gluten meal is mostly fed to dairy cattle and is a very satisfactory protein supplement for them, when fed in proper combination. Since it is much heavier than gluten feed, it is usually combined with bulkier feeds.

715. Gluten meal for beef cattle, sheep, horses, and swine.—Gluten meal is fed to beef cattle much less frequently than to dairy cows. For fattening cattle it gives fairly satisfactory results when fed as the only protein supplement, if the ration contains a reasonable amount of legume hay. Kansas experiments show that for fattening calves, the best results are secured from gluten meal when it is combined with linseed meal or certain other supplements.[84] However, a mixture of one-half gluten meal and one-half cottonseed meal was not much better than gluten meal fed as the only supplement. Probably a combination of gluten meal and soybean oil meal would give good results, because soybean oil meal has protein of excellent quality.

In 4 New York experiments corn gluten meal produced slightly less rapid gains than linseed meal, soybean oil meal, or ground soybeans, when each of these feeds was used as the only supplement for fattening yearling cattle full-fed corn grain, corn silage, and mixed hay.[85] Also, the selling price of the cattle fed gluten meal was a little lower, because they were not quite so well finished. In these trials the actual value of corn gluten meal was decidedly below that of the other supplements.

On the other hand, for wintering beef calves or yearlings in Kansas experiments, gluten meal was fully equal to cottonseed meal, linseed meal, or soybean oil meal as the supplement to sorghum silage.[86] The difference between the value of gluten meal in these trials and in the New York trials with cattle full-fed corn grain is probably due to the following: Fattening cattle full-fed grain eat relatively little roughage, and the quality of protein in corn grain is poor. Beef cattle being wintered consume mostly roughage, and the quality of the protein in satisfactory roughage, even non-legume, is better than in corn grain. (125)

Apparently because fattening lambs eat a much larger proportion of roughage than do full-fed fattening cattle, gluten meal gives decidedly better results as the only protein supplement for fattening lambs than for fattening cattle.

In 3 New York trials fattening lambs fed gluten meal as the only protein supplement to a low-protein ration made as rapid and economical gains as lambs fed soybean oil meal as the supplement.[87] These supplements were added to a ration of corn grain and corn silage, with little or no legume hay. Lambs fed linseed meal made a trifle more rapid gains than those fed gluten meal and were somewhat more easily kept on full feed. In New York metabolism experiments with growing lambs, the protein of gluten meal had as high a value as that of soybean oil meal or even that of milk. (127) For non-ruminants, the gluten meal protein would be of decidedly lower value.

Gluten meal was satisfactory as a protein supplement for work horses in an Iowa test, but it proved rather unpalatable to them.[88]

In a Kansas experiment with pigs on alfalfa pasture, gluten meal was satisfactory as the only protein supplement to corn, when bone meal was supplied to furnish phosphorus and calcium.[89] For pigs not on first-class pasture gluten meal should not be used as the only protein supplement.

Gluten meal is not quite equal to linseed meal as an ingredient in a trio supplemental mixture for growing and fattening pigs, according to a Nebraska experiment.[90]

716. Gluten meal for poultry.—Gluten meal can be used satisfactorily to replace one-half the meat scrap in poultry rations, if care is taken to provide plenty of calcium, phosphorus, and riboflavin.[91] It should not be used as the chief protein supplement, because of the deficiency in quality of protein. Corn gluten meal tends to increase the yellow color in the shanks and skin of chickens.

717. Corn oil meal or cake; corn germ meal.—The corn germs removed in the wet-milling process are dried, and then crushed and most of the oil removed. The corn oil is used for human food or other purposes. The *corn oil meal* which remains is sold as such, or it goes into corn gluten feed or sometimes into gluten meal, when there is a better market for these products than for the corn oil meal. Occasionally this feed is sold in cake form as *corn oil cake* or in the form of *corn oil flakes.*

Corn oil meal is slightly lower in protein than corn gluten feed. Unless the oil is removed by the solvent process, corn oil meal will be considerably higher in fat than gluten feed and will furnish slightly more total digestible nutrients. The protein is also of somewhat better quality than that in corn gluten feed or corn gluten meal.

Corn germ meal, produced in the dry milling of corn for corn meal, hominy grits, etc. for human consumption, generally goes into hominy feed, and very little is marketed separately. It is similar to corn oil meal in composition and value, but is slightly lower in protein and higher in nitrogen-free extract.

Most of the corn oil meal that is marketed separately is used in poultry or swine rations. It is a common ingredient in mixed poultry-fattening feeds, because of its high water-absorbing capacity. Corn oil meal is also satisfactory as a part of the concentrate mixture for dairy cattle, beef cattle, sheep, and horses.

Corn oil meal or corn germ meal should not be fed as the only protein supplement for swine [92] or poultry, but should be used in combination with supplements that furnish protein of better quality. Pigs on good pasture make fair gains when fed corn and corn germ meal, but the corn germ meal is worth little or no more than corn, ton for ton. Corn oil meal or corn germ meal is best used in swine feeding when tankage, meat scrap, or fish meal forms at least one-half of the protein supplement.

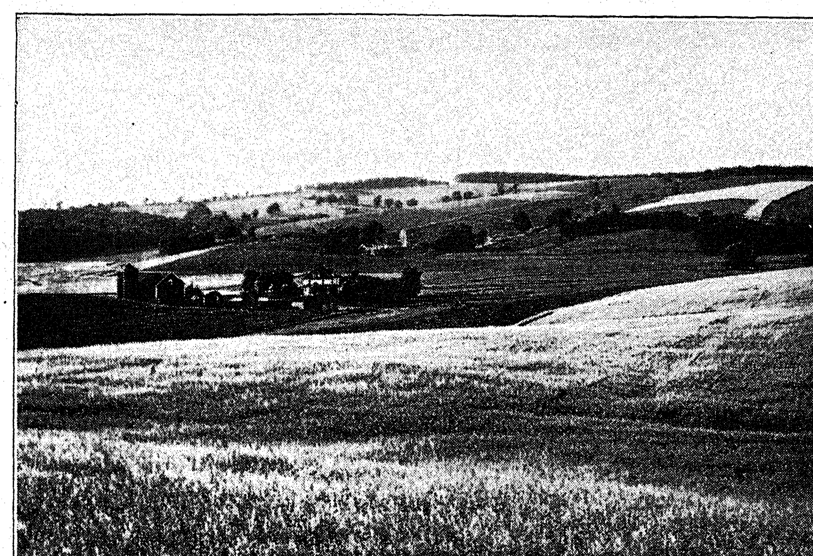
Adding corn oil meal or corn germ meal to a ration of corn and tankage did not increase the rate of gain in experiments with pigs in dry lot or on pasture. In 7 dry-lot experiments, each 100 lbs. of corn oil meal or corn germ meal replaced 42 lbs. tankage plus 45 lbs. corn.[93] In 6 pasture trials, 100 lbs. of corn germ meal replaced 46 lbs. tankage and 13 lbs. corn.[94] Corn germ meal did not produce quite as good results as linseed meal in 3 Wisconsin trials, when it was substituted for linseed meal in the trio supplemental mixture for pigs.[95]

When corn oil meal or corn germ meal have occasionally been lower in price per ton than grain, they have been used as a substitute for part of the grain in swine feeding. The results are best when these feeds do not form more than about one-fourth of the ration. Thus fed, corn oil meal or corn germ meal will be of slightly higher value per ton than corn.[96] If fed in too large amounts, these feeds may cause scours, or make the ration less palatable.

718. Corn bran.—Corn bran consists of the outer coating of the corn kernels, including the hull and the tip cap, with little or none of the starchy part of the germ. Very little corn bran is marketed as such, since it usually goes into gluten feed. Corn bran does not resemble wheat bran in composition, for it does not contain appreciably more protein than corn grain. It has nearly as much fiber as oats and furnishes about as much total digestible nutrients.

As would be expected from its composition, corn bran was decidedly inferior to ground corn as the carbohydrate feed for chicks in a Philippine test.[97]

719. Corn molasses.—Corn molasses, or hydrol, is a by-product in the manufacture of corn sugar from corn. It is usually somewhat higher than cane molasses in sugar, but is extremely low in protein. Experiments have shown it to be about equal to cane molasses in value, though it may be less palatable to stock.[98] Also, it is very viscous in cold weather.



OATS RANK NEXT TO CORN IN IMPORTANCE FOR FEEDING

Oats are an important grain crop in nearly all our states and are used for livestock feeding.

III. OATS AND THEIR BY-PRODUCTS

720. Oats as a feed.—Oats (*Avena sativa*) rank third in acreage among the cereals in the United States and are next to corn in importance for stock feeding. About three-fourths the acreage is in the North Central States, but oats are an important grain crop in nearly all the states. Where barley thrives, oats are sometimes grown in combination with it for stock feeding, as the mixture often produces a greater weight of grain.

Oats are one of the most popular stock feeds. Because of this popularity they are often higher in price, considering their actual feeding value, than the other grains which are available. Oats contain nearly as much protein as does wheat, averaging 12.0 per cent except in the Pacific Coast states. They have even more fat than does corn. Because of their hulls, oats have 11.0 per cent fiber, and they supply only 70.1 lbs. total digestible nutrients per 100 lbs., in comparison with about 80 lbs. for wheat or corn.

Oats have the same general nutritional deficiencies as the other cereals. (680) The protein is not of good quality, though probably superior to that in corn. Oats are low in calcium and only fair in phosphorus, though containing more of these minerals than does corn. Oats lack carotene and vitamin D and are low in riboflavin and niacin.

There is a great variation in the proportion of hulls in oats and consequently in their feeding value. On the average, oats contain about 30 per cent of hulls, and the standard weight per bushel is 32 lbs. Light-weight oats may be over one-half hulls, while there may be only 24 per cent of hulls in very heavy, plump oats. Oats that are high in hulls are ob-

viously low in digestible nutrients and therefore inferior in feeding value. Certain varieties grown extensively in the South and on the Pacific Coast have heavy, coarse hulls, and the kernels bear awns. This causes the weight per bushel to be low.

In buying ground oats on the market one must be careful to secure a satisfactory grade. Sometimes ground oats are made from oats of very low grade and consequently are considerably higher in fiber and lower in protein and fat than oats of good grade.

Clipped oats have been run through an oat clipper, which clips off the pointed ends of the hulls, thus increasing the weight per bushel and lowering the fiber content.

Bleached oats have been bleached by the use of sulfur or other chemicals to whiten the grain and improve the appearance. This does not increase their feeding value and may even be deleterious.

Hull-less oats, varieties from which the hulls are removed from the kernels in the threshing process, have been grown but little in this country, as the ordinary kinds with hulls have yielded much more. Recently, the South Dakota Station has produced a rust resistant variety of hull-less oats which in certain areas yields as great a weight of kernels, not including hulls, as varieties with hulls.[99] The feeding value of hull-less oats and of hulled oats (oat kernels with the hulls removed) is discussed later in this chapter. (729)

721. Oats for dairy cattle.—Oats are a most popular dairy feed, for they are very palatable, they are bulky, and they are somewhat higher than corn in protein. Experienced dairymen commonly include some ground oats in the concentrate mixture for cows and other dairy cattle, unless the price per pound is appreciably higher than that of the other grains. Oats have a higher value for dairy cows in comparison with corn than would be expected from the content of total digestible nutrients.[100] Ground oats are worth fully 90 per cent as much as ground corn for cows, and may equal corn in value when used to give bulk to a heavy concentrate mixture.

Oats should be ground to a medium fineness or crushed for dairy cows. When whole oats are fed, there is nearly as great a loss in unchewed kernels passing through the digestive tract as there is in the case of shelled corn.[101] It is not necessary to grind oats for calves up to 8 or 9 months of age.

722. Oats for beef cattle.—Because of the hulls, oats are worth less per ton than corn, if they form any large part of the concentrates for fattening cattle. Oats are often included in the grain mixture when cattle are being started on feed, but are usually omitted when the cattle are safely on feed, or at least during the latter part of the fattening period. Oats are popular as part of the concentrates for breeding cattle, for they have somewhat more protein and minerals than corn, and their bulk is no disadvantage for such cattle.

Experiments have shown that, except for calves up to about a year of age, it pays to grind oats for beef cattle, even when they are followed by pigs. Medium-fine grinding was preferable to very fine in Indiana tests.[102] In fact, the very finely-ground oats were not so valuable as whole oats. There has been no benefit from grinding oats for fattening calves up to about a year of age.[103]

When ground oats are fed as the only grain or even one-half the grain allowance to fattening cattle, they have been worth only about 85 per cent as much as corn per ton, and sometimes even less.[104] Ground oats may more nearly approach corn in feeding value for fattening cattle when they do not form more than one-third of the grain mixture.[105] Oats are also worth more for breeding cattle or for young stock being wintered than for fattening cattle. In 3 Oklahoma trials ground oats were fully equal to ground corn for wintering beef calves fed grain, cottonseed cake, silage, and ground limestone.[106]

Ground oats supply about as much total digestible nutrients as does ground snapped corn, and they proved fully equal to this feed for fattening cattle in

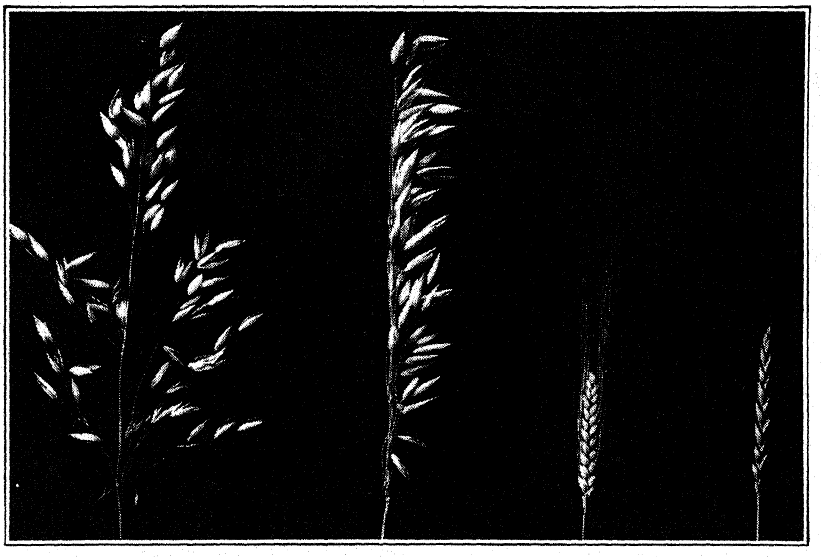
2 Florida tests, when replacing half the corn in the ration.[107]

In experiments in which ground oats have been directly compared with ground barley as the only grain for fattening cattle, the gains on oats have been nearly as rapid, on the average, but ground oats have been worth only about 86 per cent as much as ground barley.[108]

723. Oats for sheep.—Oats are well liked by sheep and are extensively used for the breeding flock, for young lambs, and for starting fattening lambs on feed. When oats are fed to fattening lambs, the proportion is generally reduced gradually as the feeding progresses. After the lambs are on full feed, the oats are usually omitted or only a small proportion is fed, along with heavier grain, such as corn or barley.

However, good-quality, heavy oats may be successfully fed as the only grain throughout the fattening period. With oats as the grain, lambs can be gotten on full feed more rapidly without danger of digestive disturbances than when heavier grain is fed. After the lambs are on full feed, they should be given all the oats they will eat, for it must be borne in mind that oats are much less concentrated than corn or barley.

In 6 Indiana experiments in which oats were thus fed in comparison with shelled corn, the gains were a trifle more rapid on oats and the lambs were as well finished as on corn.[109] While the oat-fed lambs ate more grain, they ate considerably less legume hay and silage. Considering this saving of roughage, oats equalled shelled corn in value per ton.



HEADS OF OATS, EMMER, AND SPELT

From left to right: 1, variety of oats with open or spreading panicle; 2, side oats; 3, emmer; 4, spelt.

In experiments where lambs have been fed approximately equal amounts of oats or of corn, the lambs fed oats have gained less rapidly than those receiving corn, and oats have been worth decidedly less per ton than corn. In 12 tests of this kind lambs fed oats as the only grain gained 0.33 lb. per head daily, in comparison with 0.37 lb. for those fed corn, and the oat-fed lambs required somewhat more feed per 100 lbs. gain.[110] Not considering the less rapid gains on oats, each 100 lbs. of this grain equalled in feeding value only 85.4 lbs. corn,

minus 0.3 lb. protein supplement and 10.5 lbs. hay or hay equivalent in hay and silage. At usual prices, this would make oats worth about 80 per cent as much as corn.

Oats, fed as the only grain, have been more nearly equal in value to barley for fattening lambs in experiments where these grains have been compared, and in some tests have been fully equal to barley.[111] When lambs are gotten on feed rapidly with oats and then fed all of this grain they will eat, it is probably safe to estimate that oats will be worth at least 90 per cent as much as barley. Light-weight oats are, of course, worth much less than heavy oats.

Oats are a popular concentrate for pregnant ewes or ewes nursing lambs. Because of the lower net-energy value of oats, it will require somewhat more oats than corn or barley to keep the ewes in proper condition, but less roughage will be eaten. In Indiana trials each 100 lbs. of oats was equal to 62 lbs. corn plus 43 lbs. hay for ewes nursing lambs.[112]

It is unnecessary to grind oats for sheep. On the average, fattening lambs have made more rapid and economical gains on whole oats than on ground oats.[113] Sheaf oats may be fed to breeding ewes in the winter, thus saving the expense of threshing.

724. Oats are the standard grain for horses.—Oats are such an excellent grain for horses that they are the standard with which other concentrates are compared. Because of the bulky hulls, oats are the safest of all grains for the horse. They form a loose mass in the stomach that can be easily digested, while such heavy feeds as corn, wheat, or barley tend to pack, sometimes causing colic. Even if a horse gains access to the grain bin and gorges on oats, there is much less danger of serious digestive trouble than with the heavier grains.

Oats contain sufficient protein so that merely oats and hay from timothy or other grasses make a balanced ration for mature horses, without adding any protein supplement. Since oats are lower than corn or barley in total digestible nutrients, a somewhat greater weight of oats is required to keep work horses in condition. For horses at very hard work a mixture of oats with corn or barley is better than oats as the only grain.

Grinding or crushing oats for horses whose teeth are kept in good condition increases the value only about 5 per cent.[114] If whole oats are mixed with chopped hay or straw, the saving through grinding is even less.[115] For horses with poor teeth and for foals up to 7 or 8 months of age, grinding or crushing oats is advisable. When oats are not combined, sheaf oats (unthreshed oats in the bundle) are an economical feed for horses, since the cost of threshing is saved and much of the straw is used. New or musty oats should not be fed to horses, as they may cause colic.

While oats are unexcelled for horses, both scientific experiments and the experience of farmers have shown clearly that other grains and also combinations of grains and other concentrates may be substituted for oats without injury to the condition, the wind, the endurance, or even the spirit of horses.

725. Oats for swine.—Oats are satisfactory as part of the ration for swine, but they are too high in fiber and too bulky to be the chief concentrate. Ground oats are worth about as much as corn per 100 lbs. when forming a rather small part of the ration, but when fed in large amounts, they are worth much less than corn, barley, or wheat. Heavy oats, containing a small percentage of hulls, are much better for swine than light oats and may satisfactorily form a somewhat larger part of the ration. Since oats are higher than corn in protein, a little less protein supplement is needed when part of the corn is replaced by oats.

For growing and fattening pigs oats should generally form not more than one-third and preferably not more than one-fourth of the ration. In 20 experiments with pigs in dry lot, when ground oats was fed as not over one-fourth of a well-balanced ration to replace part of the corn, the rate of gain was increased a trifle.[116] Each 100 lbs. of oats replaced enough corn and protein sup-

plement to make the value of the ground oats just about equal to that of corn per 100 lbs.

Oats apparently have a lower value for pigs on pasture, probably because pasture forage itself is bulky. In 9 experiments with pigs on pasture, when oats were similarly added to corn and protein supplement they were worth only 82 per cent as much as corn.[117]

If pigs are fed a larger proportion of oats, the gains are usually slower and the oats worth considerably less. Pigs fed ground oats as the only grain with good protein supplements gained decidedly less in 24 trials than others fed corn and supplement.[118] Without considering the slower gain, the oats were worth 79 per cent as much as corn.

Occasionally, when pigs are self-fed corn and tankage or some other protein supplement, free-choice, ground oats are also provided in a compartment of the self-feeder. When this is done, the pigs generally eat very little of the oats.[119] Therefore, if one desires to use oats for pigs, it is best to mix the ground oats with corn or other grain.

For brood sows before their litters are farrowed, ground oats can form one-half of the ration without appreciably reducing the efficiency.[120] By 2 or 3 weeks after farrowing, the proportion of oats should be reduced to one-fourth or one-third, so as to stimulate the milk flow with a more concentrated ration.

Oats should be ground for swine, as grinding generally increases the value of the grain 25 per cent or more. Fine grinding was preferable to coarser grinding in a Canadian trial, but in Indiana trials medium-fine grinding was fully as good as fine grinding.[121] Soaking whole oats does not increase their value appreciably.

When forming a large part of the ration for pigs, oats tend to produce fat which is a little softer than that produced on corn.

726. Oats for poultry.—Oats are desirable in poultry rations because of certain special qualities, even though they rank below corn or wheat in supplying total digestible nutrients or net energy. Because of the hulls, the use of oats in poultry rations tends to prevent feather picking and cannibalism.[122] Also, the hulls seem to provide a factor that improves the growth and feather development of chicks and helps prevent mortality.[123]

Plump heavy oats should be used for poultry since the hulls seem to furnish no net energy for them. If light-weight oats are fed, one should keep the fiber content of the rest of the ration rather low.

According to Ohio studies, good methods of supplying oats to laying hens are to feed whole oats, free-choice in hoppers, in addition to feeding mash separately, or else to mix 20 per cent of whole oats in the mash.[124] Feeding oats in such a manner was of especial importance with chickens that were closely confined.

For laying hens, as much as 40 to 50 per cent of oats gives satisfactory results, if the oats are heavy and plump.[125] However, a considerably smaller proportion is ordinarily used.

In Texas studies it was estimated that for chickens oats of good grade, containing 30 per cent hulls, supplied about 75 per cent as much net energy per pound as did No. 2 corn, and about 80 per cent as much as wheat.[126] When the proportion of oats is not too large, it seems, however, to have a higher relative value than this for laying hens. Thus, in 3 Texas experiments it was concluded that oats were equal to corn for layers, when thus substituted for it, pound for pound.[127]

Usually, not more than 10 to 15 per cent of ground oats is included in starting mashes for chicks. Too large a proportion may cause digestive disturbances. Using a large percentage of ground oats in a ration for broilers decreases the rate of gain. Sometimes rolled oats or feeding oat meal (not including the hulls) is used as an ingredient in the mash for chicks.

727. Corn-and-oat feed.—This feed, also called corn-and-oat chop, ground corn and oats, ground feed, and provender, is extensively used in the eastern

and southern states for dairy cows and especially for horses and mules. In composition it ranges from a mixture of various proportions of good-grade corn and oats to one containing a large proportion of low-grade materials, such as oat hulls and ground corn cobs. The best guide to the purity is the fiber content. When corn-and-oat feed contains over 7 to 8 per cent fiber, it has either been adulterated or made from poor-quality oats.

728. Oat by-products.—In the method now used in making oatmeal for human consumption, the hulls and particles of the oat kernel, or groat, are combined to form the product called *oat mill by-product.* According to the definition proposed by the Association of American Feed Control Officials, this should not have more than 32 per cent fiber.[67] Since *oat hulls* do not generally have more fiber than this, oat mill by-product as now produced evidently consists almost entirely of oat hulls, with only traces of particles of the oat kernels. The feeding value of this by-product is consequently not appreciably higher than that of oat hulls.

Until the milling process was changed recently, the by-product known as *oat mill feed* had about 84 per cent of oat hulls and 16 per cent of fragments of the kernels. Extensive Wisconsin and other experiments showed that such oat mill feed could be used as a substitute for part of the grain ordinarily fed to dairy cows, beef cattle, sheep, and horses.[128] Thus used, this oat mill feed was worth about 30 to 40 per cent as much as corn grain. Used as a substitute for part of the hay, the value of oat mill feed ranged from that of timothy hay to not appreciably more than that of chopped oat straw. The oat mill by-product now produced in this country undoubtedly has a lower value than the former oat mill feed, because it has a smaller percentage of fragments of the kernels.

Oat hulls are a low-grade roughage, since they supply less total digestible nutrients than oat straw or even wheat straw.

Clipped oat by-product (also called "oat clippings") is the by-product obtained in the manufacture of clipped oats. It may contain, according to the definition of the Association of American Feed Control Officials, the light chaffy material broken from the ends of the hulls, and also empty hulls, light immature oats, and dust.[67] It must not have an excessive amount of hulls. This by-product averages 8.8 per cent in protein and has 25.3 per cent of fiber. It is therefore worth somewhat more than oat mill by-product. Clipped oat by-product is chiefly used as an ingredient in certain mixed feeds.

729. Hulled oats; feeding oat meal; steel-cut oats; hull-less oats.—Occasionally oats for feeding are run through hulling machines which grind the grain and remove most of the hulls. Generally not over 85 to 90 per cent of the kernels are recovered in the *hulled oats,* the rest going with the hulls. It takes 155 to 165 lbs. of whole oats to produce 100 lbs. of hulled oats. Hulled oats are a high-grade feed, but usually expensive. They are sometimes used in pig starters or in mashes for chicks. For growing and fattening pigs ground oats are decidedly more economical.

In 9 experiments with growing and fattening pigs, the addition of a limited amount of hulled oats to a ration of corn and protein supplement has increased the rate of gain slightly.[129] Each 100 lbs. of hulled oats (made from 155 to 165 lbs. of whole oats) saved enough corn and protein supplement to equal about 140 lbs. of corn in value. In these trials the oats before hulling were therefore worth decidedly less than corn per pound. Similar results were secured in 2 Illinois tests with weanling pigs, when one-third hulled oats was included in the ration.[130]

Feeding oat meal, a by-product in the manufacture of rolled oats, consists of broken pieces and fragments of the rolled kernels and floury portions of the kernels, with only such quantity of finely ground oat hulls as is unavoidable in the usual process of commercial milling. According to the definition of the Association of American Feed Control Officials, it must not have more than 4 per cent of fiber.[67] *Steel-cut oats* consist of hulled oat kernels that have been cut into pieces. These feeds are generally used in chick mashes or pig starters.

Hull-less oats have the same composition as hulled oats and resemble wheat, except that they have more fat. They are an excellent feed where they can be produced economically.[131]

730. Sprouted oats.—For a time, sprouted oats were used to a considerable extent in the winter feeding of poultry to furnish a green and succulent feed. With the advances in knowledge concerning the importance of vitamins and other factors in poultry nutrition, efficient rations were developed that made the labor and expense of sprouting oats unnecessary. Therefore the practice has been practically discontinued.

It was claimed some years ago that the

feeding of sprouted oats aided in overcoming sterility in dairy cows and heifers that had failed to conceive from repeated services. However, experiments have shown that sprouted oats are not usually beneficial in such cases.[132]

QUESTIONS

1. Discuss the general nutritive characteristics of the cereal grains, considering amount and quality of protein, amounts of calcium and phosphorus, and content of the various vitamins.
2. Discuss the composition and the special nutritive characteristics of corn grain.
3. Compare the feeding value of yellow corn and white corn under various conditions.
4. What various types of corn are grown? Compare the value of flint corn and dent corn; of hybrid corn and the older open-pollinated varieties.
5. What is the approximate upper limit of moisture for safe storage of ear corn in a crib; for safe storage of shelled corn in a bin?
6. How may soft corn be utilized?
7. In what forms is corn grain fed to stock?
8. Compare the composition and nutritive value of corn cobs and of corn grain.
9. How can ground corn cobs be utilized for: (a) Wintering beef cattle; (b) fattening beef cattle; (c) dairy cattle?
10. Discuss the use and value of corn for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry. For each class of stock, state the forms in which corn is usually fed.
11. Discuss the composition of the different parts of the corn kernel.
12. What is hominy feed? Compare the composition and feeding value of hominy feed and corn.
13. Describe the manufacture of starch from corn and name the by-products produced.
14. Of what is corn oil meal composed and what is its usual composition?
15. Discuss the composition and feeding value of corn gluten feed; corn gluten meal.
16. How does corn germ meal differ from corn oil meal?
17. Discuss the composition of oats in comparison with that of corn, and state the classes of livestock to which oats are most commonly fed in your district.
18. Discuss the use and value of oats for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses; (e) swine; (f) poultry.
19. How could you tell from the guaranteed composition whether or not a particular lot of corn-and-oat feed was of good grade?
20. What is the chief by-product in the manufacture of oat meal? Discuss its composition and feeding value.
21. For what classes of stock are oat meal or hulled oats sometimes used?

REFERENCES

1. Feeds and Feeding, 20th Ed., p. 980.
2. Schneider, Lucas, and Beeson, Report for Committee on Feed Composition, Nat. Research Council, Publication 258; Jour. Agr. and Food Chem., 1, 1953, pp. 172–177.
3. Sauberlich, Chang, and Salmon, Ala., Jour. Nutr., 51, 1953, pp. 241–250; Leonard and Clark, Colo. Tech. Bul. 19; Ill. Rpts. 1948, 1948–50; Norden, Rossman, and Benne, Mich. Quar. Bul., 34, 1952, No. 3; Jordan et al., Miss. Farm. Res., 13, 1950, No. 4; Richter, Penn. Science for the Farmer, June, 1948; see also: Pendleton et al., Ill. Buls. 536, 544.
4. Webster, Brooks, and Cross, Okla. Tech. Bul. B-36; Prince and Eskew, S.C. Rpt. 63.
5. Sauberlich, Chang, and Salmon, Ala., Jour. Nutr., 51, 1953, pp. 623–635; Mitchell, Hamilton, and Beadles, Ill., Jour. Nutr., 48, 1952, pp. 461–476; Ross et al., Ill., Mimeo. Rpt. A.S. 267; Fox and Sprague, Iowa Rpt. 1946, Part 2; Miller, Hurst, and Brimball, Iowa, Agron. Jour., 44, 1952, pp. 343–345; Hogan et al., Mo. Bul. 621; Eggert, Brinegar, and Anderson, Nebr., Jour. Anim. Sci., 12, 1953, pp. 282–290; see also: Miller, Aurand, and Flach, Penn., Science, 112, 1950, pp. 57–58.
6. Dobbins, Krider, Hamilton, and Earley, Ill., Jour. Anim. Sci., 9, 1950, pp. 625–633, 654; Ross et al., Ill. Mimeo. Rpt. A.S. 267; Miss. Rpt. 64; Eggert, Brinegar, and Anderson, Nebr., Jour. Anim. Sci., 12, 1953, pp. 282–290.
7. Bond, Neumann, Forbes, and Norton, Ill., Jour. Anim. Sci., 13, 1954, pp. 977–978; Ross, Garrigus, Hamilton, and Earley, Ill., Jour. Anim. Sci., 13, 1954, pp. 433–437; Nevens et al., Ill. Bul. 586.
8. Neale, N. Mex. Bul. 350; Morrison, Hulce, and Humphrey, Wis. Bul. 339.
9. Morrison, Bohstedt, and Fargo, Wis. Buls. 323, 339, 352; see also: Grimes and Sewell, Ala. Rpts. 1929, 1930, 1931; Martin, Ark. Bul. 321; Tomhave, Del. Bul. 147; Rice, Mitchell, and Laible, Ill. Bul. 281; Lamb and Evvard, Iowa, Amer. Soc. Anim. Prod., Proc. 1923; Snyder, Nebr. Bul. 214; Loeffel, Nebr. Rpt. 1921; Nebr. Rpt. 1934; Hostetler, Foster, and Halverson, N.C. Tech. Bul. 52; Livesay and Stillwell, West Va. Bul. 213.
10. Polk, Miss. Farm Res. 3, 1940, No. 3.
11. Robison, Ohio Bimo. Bul. 228.
12. Hanson, Nebr., Jour. Anim. Sci., 5, 1945, pp. 36–41.
13. Mussehl, Nebr. Rpt. 1943.
14. Ill. Rpt. 1938–47; Vestal, Ind. Rpts. 1940, 1941; Culbertson, Anderson, Robinson, and Hammond, Iowa Bul. 375; Culbertson,

Shearer, and Robinson, Iowa Rpt. 1940, Part 2; Rpt. 1941, Part 2; Ky. Rpts. 1942, 1943, 1944; Ferrin and Johnson, Minn., mimeo. rpt.; Weaver, Mo. Buls. 457, 477; Trowbridge, Comfort, and Dyer, Mo. Bul. 457; Nebr. Rpts. 1939, 1940; Ackerson, Ham, and Mussehl, Nebr. Res. Bul. 144; Robison, Ohio Bimo. Buls. 201, 205, 228; Gerlaugh, Ohio Bimo. Bul. 205; Blizzard and Taylor, Okla. Mimeo. Cir. 72.

15. Rusk and Snapp, Ill. Bul. 313; Ill. Cir. 293; Bull, Olson, and Longwell, Ill. Bul. 355; Rusk et al., Ill. Cir. 586; Evvard et al., Iowa Buls. 216, 273; Bechtel, Atkeson, Fenton, and Carleton, Kan., Jour. Anim. Sci., 4, 1945, pp. 438–452; Light, N.D. Bimo. Bul., 16, 1953, No. 1; Robison, Ohio Bul. 362; Ohio Bimo. Bul. 228; R.I. Quar. Res. Review, 3, 1952, No. 2; Olson et al., S.D. Bul. 433; Shedd, U.S.D.A. Farmers' Bul. 1976.
16. Culbertson and Shearer, Iowa Rpt. 1946, Part 2; Dunn, Ely, and Huffman, Mich., Jour. Dairy Sci., 30, 1947, pp. 567–568.
17. Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732; Chappel, Sirny, Whitehair, and MacVicar, Okla., Jour. Anim. Sci., 14, 1955, pp. 153–159; Swift et al., Penn., Jour. Anim. Sci., 10, 1951, pp. 434–438; Lindahl, U.S.D.A., Agr. Res., 4, 1955, No. 2.
18. Beeson, Perry, et al., Ind. Mimeo. Rpts. A.H. 48, 54, 58, 63, 64, 66, and 123; Beeson and Perry, Ind., Jour. Anim. Sci., 11, 1953, pp. 501–515; see also: Burroughs and Culbertson, Iowa, Mimeo. Rpt. A.H. 581.
19. Smith et al., Kan. Cirs. 297, 308.
20. Burr and Adams, Nebr. Cir. 93; Baker and Jackson, Nebr. North Platte Substation Prog. Rpt. 67.
21. Barrick et al., N.C. Res. and Farming, 10, 1951, No. 2.
22. Gerlaugh and Rogers, Ohio Farm and Home Res., Nos. 254, 263; Gerlaugh, and Burroughs, Ohio Farm and Home Res., No. 258; Baker and Arthaud, Nebr. Bul. 396; Culbertson, Iowa Farm Res., 2, 1947, No. 1.
23. Burroughs, Iowa, Assoc. Amer. Feed Control Officials, Official Publication, 1955; see also: Geurin, Thompson, Wilcke, and Bethke, Jour. Anim. Sci., 14, 1955, pp. 797–806.
24. Hill, Hatcher, Lundquist, and Crowl, Ind., Jour. Dairy Sci., 36, 1953, p. 581; Graf and Engel, Va., Jour. Dairy Sci., 36, 1953, pp. 580–581; Graf and Hardison, Va. Rpt. 1950–53.
25. Thompson, Graf, Eheart, and Holdaway, Va., Jour. Dairy Sci., 35, 1952, pp. 1010–1016.
26. Harshbarger, Ill., Jour. Dairy Sci., 38, 1955, pp. 1164–1168.
27. Fries, Lassiter, Seath, and Rust, Ky., Jour. Anim. Sci., 14, 1955, p. 1203.
28. Bell, Ohio Res. Bul. 690; Beeson, Harper, and Perry, Ind. Rpt. 66.
29. Moore and Henderson, W. Va., Jour. Dairy Sci., 23, 1940, pp. 551–552.
30. Fraser and Hayden, Ill. Bul. 159; see also: Patterson, Md. Bul. 84.
31. McCandlish and Weaver, Iowa Bul. 195; Shaw and Norton, Mich. Bul. 242; Olson, S.D. Bul. 358 and Cir. 34; Darnell and Copeland, Tex. Bul. 530.
32. Wilbur, Ind. Bul. 372; see also: Keener et al., N.H. Bul. 419.
33. Hilton, Wilbur, and Heinton, Ind. Bul. 373; McCandlish, Iowa Res. Bul. 51; Otis, Kan. Bul. 126; Fain and Jarnagin, Va. Bul. 172.
34. Shaw and Norton, Mich. Bul. 242.
35. McCandlish and Weaver, Iowa Bul. 195; Fitch, Cave, Riddell, and Merrill, Kan. Rpts. 1928–30, 1932–34; Cook, N.J. Rpt. 25.
36. Monroe and Krauss, Ohio Bimo. Bul. 240.
37. Culbertson, Shearer, and Robinson, Iowa Rpt. 1942, Part 2; Cochel, Kan., information to the author; Allison, Mo. Bul. 149; Trowbridge, Moffett, and Hazen, Mo. Bul. 328; Thalman and Gramlich, Nebr. Rpt. 1935; Thalman, Nebr. Bul. 354; Gerlaugh, Ohio Bul. 446; Jacob, Duncan, Neel, and Hazlewood, Tenn. Cir. 69.
38. Gerlaugh and Kunkle, Ohio Farm and Home Res., Nos. 254, 263; see also: Baker, Nebr., North Platte Sta. Progress Rpt. 52; Baker and Arthaud, Nebr. Bul. 396.
39. Beeson, Mott, and Brown, Ind., Mimeo. Rpts. A.H. 33, 39.
40. Guerin, Thompson, Wilcke, and Bethke, Jour. Anim. Sci., 14, 1955, pp. 797–806.
41. Mumford, Ill. Bul. 103; Good and Horlacher, Ky. Cir. 26; Peters, Minn. Bul. 300; Allison, Mo. Bul. 149; Trowbridge and Moffett, Mo. Bul. 310.
42. Gramlich, Nebr. Bul. 174; Thalman and Gramlich, Nebr. Rpt. 1934.
43. Jacob, Duncan, Neel, and Hazlewood, Tenn. Cir. 69.
44. Georgia Coastal Plain Buls. 42, 49; see also: Hentges, Cunha, and Killinger, Fla. Rpt. 1953.
45. Ga. Coastal Plain Buls. 46, 48.
46. Skinner and King, Ind. Bul. 162; Burnett, Nebr. Bul. 66; Emery, Wyo. Bul. 51; Morton, Wyo. Bul. 73; Faville, Wyo. Bul. 85.
47. Coffey, Productive Sheep Husbandry, pp. 375–376; Evvard, Shearer, Culbertson, and Wallace, Iowa Bul. 299; Paterson. Kan. Cir. 88; Brown, Mich. Quar. Bul., 16, 1933, No. 1 and mimeo. rpt.; Jordan and Peters, Minn. Bul. 306; Jordan, Croom, and Ferrin, Minn., mimeo. rpt.; Hackedorn, Mo. Bul. 147; Weber and Loeffel, Nebr. Bul. 257; Bell, Ohio Res. Bul. 690.
48. Coffey, Productive Sheep Husbandry, pp. 375–376; Skinner and King, Ind. Buls. 273, 282, 296; Evvard, Shearer, Culbertson, and Wallace, Iowa Bul. 299; Jordan and Peters, Minn. Bul. 306.
49. Brown, Mich. Spec. Bul. 233.
50. Newsom and Cross, Colo. Bul. 474; Kammlade, Ill. Bul. 338; Foster, Mo. Bul. 244; Gramlich, Nebr. Buls. 167, 170; Bell, Ohio Buls. 382, 402; Bell and Thatcher, Ohio Bimo. Bul. 128; Wilson and Kuhlman, S.D. Bul. 207.
51. Trowbridge, Mo. Cir. 125; see also: Edmonds and Kammlade, Ill. Bul. 238; Gray and Hostetler, N.C. Dept. Agr., Bul., Sept., 1922; Carmichael, Ohio Bul. 195.
52. McCampbell, Kan. Bul. 186; Templeton, Miss. Bul. 244.
53. Plumb and Van Norman, Ind. Bul. 90; Good, Ky. Bul. 175; Weaver, Mo., information to the author; Loeffel, Nebr., information to the author; Robison, Ohio Buls. 316, 349.
54. Hogan, Kan., Jour. Biol. Chem., 29, 1917, pp. 485–493; Vestal, Ind., mimeo. rpt.; Robison, Ohio Buls. 316, 349.
55. Robison, Ohio Bul. 705; Grummer and Bohstedt, Wis., Hoard's Dairyman, Sept. 10, 1953.
56. Vestal, Ind., mimeo. rpts.; Ferrin and Johnson, Minn., mimeo. rpts.; Bohstedt et al., Wis., Amer. Soc. Anim. Prod., Proc. 1931.
57. Garrigus and Mitchell, Ill. Rpt. 1934, and

Jour. Agr. Res., 50, 1935, pp. 731–735; King, Ind., Amer. Soc. Anim. Prod., Proc. 1913; Vestal, Ind., mimeo. rpt.; Kennedy and Robbins, Iowa Bul. 106; Evvard, Iowa, mimeo. rpt.; Aubel and Connell, Kan., mimeo. rpt.; Weaver, Mo., mimeo, rpt.; Loeffel, Nebr., mimeo. rpt.; Robison, Ohio Buls. 362, 516, 552, and Ohio Spec. Cir. 39; Penn. Bul. 147; Wilson and Wright, S.D. Bul. 252; Henry and Otis, Wis. Bul. 145 and Wis. Rpt. 1906; Wyo. Rpt. 1933.

58. Evvard, Wallace, and Culbertson, Iowa Bul. 245.
59. McCarty, Nicholas, and Keith, Penn. Bul. 326; Bohstedt, Roche, Fargo, Rupel, and Duffee, Wis., Amer. Soc. Anim. Prod., Proc. 1931.
60. Kennedy and Robbins, Iowa Bul. 106; Robison, Ohio Bul. 665; Ziegler, Penn. Bul. 488; Grummer and Bohstedt, Wis., Hoard's Dairyman, Sept. 10, 1953; see also: Grummer, Farm Journal, Feb., 1954.
61. Ga. Coastal Plain Bul. 49.
62. Kirk, Gratz, and Whitehurst, Fla. Bul. 389; Southwell and McCormick, Ga. Coastal Plain Bul. 49; Carroll et al., Ill. Rpt. 1927; Vestal, Ind. Rpts. 1922, 1927; Evvard, Iowa Bul. 143; Evvard, Culbertson, et al., Iowa Rpts., 1924, 1926, 1927; Anderson and Marston, Kan. Cir. 118; Good, Ky. Rpts. 1918, 1919, 1920, 1921, 1922, 1923, 1924, 1925, 1926; Bray and Francioni, La. Bul. 236; La. Rpts. 1948, 1950, 1952; Edwards, Mich. Spec. Bul. 200, and Mich. Quar. Bul., 7, 1924, No. 1; Gaumnitz, Wilson, and Bassett, Minn. Bul. 104; Selvig and Kiser, Minn., Crookston Substa. Rpt. 1923; Ferrin and Jessup, Minn., mimeo. rpt.; Weaver, Mo. Bul. 224; Hansen, Mont. Bul. 193; Vinke and Morgan, Mont. Bul. 257; Holden, Nebr. Bul. 159; Loeffel, Nebr., mimeo, rpt.; N.J. Rpts., 1924, 1926; N.C. Rpt. 1927; Shepperd, N.D. Bul. 174; Douglas and Langford, N.D. Bul. 396; Robison, Ohio Bul. 398; Wilson and Kuhlman, S.D. Bul. 192; Thomas, Kincaid, and Taylor, Va. Rpts. 1942–49, 1950, 1950–53; Seamans and Hutton, U.S.D.A. Cir. 330.
63. Kennard and Chamberlin, Ohio Bimo. Bul. 241.
64. Roberts and Carrick, Ind. Rpt. 1941; Ind. Rpts. 1935, 1936; Kempster, Mo. Bul. 490; see also: Wightman, West Va. Bul. 298.
65. Heuser, N.Y., Poultry Sci., 22, 1943, pp. 123–125; Kennard and Chamberlin, Ohio Bimo. Bul. 181.
66. Hopkins, Ill. Bul. 87.
67. Assoc. Amer. Feed Control Officials, Official Pub., 1956.
68. Borland, Penn. Bul. 446; Murdock, Bechdel, and Borland, Feedstuffs, Dec. 26, 1942.
69. Cochel, Kan., mimeo. rpt.; Branaman, Fick, and Harrison, Mich. Quar. Bul., 25, 1943, No. 4; Thalman, Nebr. Bul. 355; Miller and Pierce, N.Y., mimeo. rpt.
70. Skinner, Vestal, and Starr, Ind. Buls. 221, 234; Harper, Ind. Bul. 304; Evvard, Dunn, and Culbertson, Iowa Bul. 210; Paterson, Kan. Cir. 79; Gramlich, Nebr. Bul. 173.
71. Harper, N.Y. (Cornell) Bul. 437.
72. Skinner and Starr, Ind. Bul. 219; Vestal and Shrewsbury, Ind. Bul. 501; Evvard, Dunn, and Culbertson, Iowa, mimeo. rpts.; Gramlich and Jenkins, Nebr. Bul. 175; Gramlich, Nebr. Bul. 176; Gramlich and Loeffel, Nebr., mimeo. rpt.; Loeffel, Nebr., mimeo. rpt.; Robison, Ohio Bul. 607.
73. Vestal and Shrewsbury, Ind. Bul. 501.
74. Davidson, McCrary, and Card, Mich. Quar. Bul., 27, 1945, No. 3.
75. Beeson, Hoefer, and Guerin, Ind. Rpt. 1950.
76. Morrison, Bratton, and Salisbury, N.Y. (Cornell) Rpts. 1941, 1942, and Jour. Dairy Sci., 26, 1943, pp. 730–731.
77. Savage, Harrison, and Norton, N.Y. (Cornell) Rpt. 1943.
78. Caldwell, Ind. Bul. 203.
79. Evvard, Dunn, and Savin, Iowa, mimeo. rpt.; Paterson, Kan. Cirs. 79, 88; Kiser and Peters, Minn. Bul. 261; Morrison and Kleinheinz, Wis. Bul. 323.
80. Evvard, Dunn, and Culbertson, Iowa Buls. 185, 210.
81. Hays, Del. Bul. 124; Evvard, Iowa, mimeo. rpt.
82. Evvard et al., Iowa Leaflets 11, 18; Ashby, Minn. Rpt. 1918; Loeffel, Nebr., mimeo. rpt.
83. Heuser and Norris, N.Y. (Cornell) Bul. 810; Slinger, Pettit, and Evans, Sci. Agr., Canada, 24, 1944, p. 234.
84. Weber and Connell, Kan. Rpt. 1932–34.
85. Hinman, Morrison, Miller, Hobbs and Wanderstock, N.Y. (Cornell) Rpts. 1940, 1941, and mimeo. rpt.
86. McCampbell and Aicher, Kan., Annual Cattlemen's Roundup, 1938, 1939; see also: Pope, Stephens, Darlow, and Heller, Okla. Misc. Pub. MP-27.
87. Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834; see also: Jordan and Peters, Minn. Bul. 306; Alexander and Weber, Nebr., mimeo. rpt.
88. Kennedy, Robbins, and Kildee, Iowa Bul. 109.
89. Aubel and Alexander, Kan. Cir. 287.
90. Loeffel, Nebr., mimeo. rpt.
91. Mussehl, Ackerson, and Borchers, Nebr. Rpt. 62; Ringrose, Norris, and Heuser, N.Y. (Cornell) Bul. 725; Clark, VanLandingham, and Runnels, West Va. Bul. 208; see also: Ky. Rpt. 1949.
92. Skinner and Starr, Ind. Bul. 219; Evvard, Iowa, mimeo. rpts.; Robison, Ohio Bul. 349.
93. Skinner and Starr, Ind. Bul. 219; Evvard, Iowa, Live Stock Health Jour., Nov. 1, 1920; Loeffel, Nebr., mimeo. rpts.; Robison, Ohio Mo. Bul. 57.
94. Evvard, Iowa, mimeo. rpts.; Morrison and Fargo, Wis. Bul. 373.
95. Morrison, Fargo, and Thomas, Wis. Bul. 388; Fargo and Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1929.
96. Robison, Ohio Bul. 607.
97. Tolentino, Philippine Agr., 24, 1935, pp. 413–424.
98. Colo. Rpt. 1940; Rusk and Snapp, Ill. Rpt. 1938; Culbertson and McDonald, Iowa Rpt. 1949; Jacobson, Wise, Cannon, and Owen, Iowa Farm Sci., 4, 1950, No. 7; Thalman, Nebr. Bul. 355; Fargo, Bohstedt, and Lacey, Wis. Bul. 454.
99. Grafius and Dirks, S.D. Rpt. 63; S.D. Bul. 401.
100. Seath and Henderson, La. Rpt. 1947; Lindsey, Mass. Rpt. 1913, Part 1; Scandinavian Feed Unit System.
101. Ind. Rpt. 1927; Shaw and Norton, Mich. Bul. 242; see also: Olson, S.D. Bul. 358; Wallis and Olson, S.D. Cir. 34; Darnell and Copeland, Tex. Bul. 530.
102. Skinner and King, Ind. Bul. 371.
103. Weber and Connell, Kan. Rpt. 1932–34; Peters, Minn. Bul. 300; Blizzard and Taylor, Okla. Bul. B-270.

104. Skinner and King, Ind. Bul. 371; Weber and Connell, Kan., mimeo. rpt.; Branaman and Brown, Mich. Spec. Bul. 280; Miss. Rpts. 1941, 1942; Morrison, Miss. Farm Res., 17, 1954, No. 5; Thalman, Nebr. Bul. 355; Miller and Pierce, N.Y., mimeo. rpt.; Blizzard and Taylor, Okla. Bul. B-270; Wilson, S.D. Bul. 160.
105. Skinner and King, Ind. Buls. 330, 371; Evvard, Culbertson, et al., Iowa Rpt. 1924; Culbertson and Hammond, Iowa, mimeo. rpt.; Peters, Minn. Bul. 300, Miss. Rpts. 1942, 1943.
106. Blizzard and Taylor, Okla. Bul. B-270.
107. McCormick and Glasscock, Fla. Rpts. 1943, 1944.
108. Kiser and Peters, Minn. Bul. 261; Linfield, Mont. Bul. 58; Fuller, Wis., mimeo. rpt.
109. Harper, Ind. Buls. 312, 325, 333; King and Harper, Ind. Bul. 360.
110. Evvard, Dunn, and Culbertson, Iowa Bul. 210; Brown, Mich. Spec. Bul. 233; Jordan and Peters, Minn. Bul. 306; Potter and Dean, Ore. Bul. 198; Hackedorn, Sotola, and Singleton, Wash. Bul. 258.
111. Dickson and Hansen, Mont., mimeo. rpt.; Linfield, Mont. Buls. 47, 49; Joseph, Mont., mimeo. rpt.; Briggs, Okla. Bul. B-272; Richards, Ore. Bul. 370.
112. Harper, Ind. Bul. 419; see also: Hodgson et al., Id. Bul. 272; Wilson, Johnson, and Wright, S.D. Bul. 288.
113. King and Harper, Ind. Bul. 360; Jordan and Peters, Minn. Bul. 272; Hackedorn, Sotola, and Singleton, Wash. Buls. 258, 275.
114. Morrison, Fuller, and Bohstedt, Wis. Bul. 302.
115. Lavalard, Expt. Sta. Rec., 12, 1900, p. 12.
116. Summarized by Robison, Ohio Bul. 607; see also: Dinusson, Klosterman, Holm and Buchanan, N.D. Bimo. Bul., 14, 1952, No. 5.
117. Vestal, Ind., mimeo. rpt.; Robison, Ohio Bul. 607.
118. Carroll, Ill. Cir. 414; Peters, Ferrin, and Johnson, Minn., mimeo. rpt.; Bedenbaugh, Miss. Bul. 410; Weaver, Mo. Bul. 444; Loeffel, Nebr. Rpts. 1937, 1940; Robison, Ohio Bul. 607; Thompson, Okla. Rpt. 1919; S.D. Rpts. 1926, 1938.
119. Grummer and Bohstedt, Wis., Hoard's Dairyman, Sept. 10, 1953.
120. Hanson, Holt, and Ferrin, Minn., mimeo. rpt.; see also: Carroll and Smith, Ill. Rpt. 1927; S.D. Rpt. 1926.
121. Crampton and Bell, Canada, Jour. Anim. Sci., 5, 1946; pp. 200–210; Vestal, Ind., mimeo. rpts.
122. Kennard and Chamberlin, Ohio Bimo. Buls. 181, 220; Ringrose and Morgan, S.C. Rpt. 1938; Miller and Bearse, Wash., Poultry Sci., 16, 1937, pp. 314–321; Bearse, Miller, and McClary, Wash., Poultry Sci., 19, 1940, pp. 210–215.
123. Sanford and Wilcke, Iowa, Poultry Sci., 23, 1944, pp. 298–309; Record, Iowa Res. Bul. 312; Miss. Rpt. 1941.
124. Kennard and Chamberlin, Ohio Bimo. Buls. 181, 200.
125. Lampman and Thompson, Id. Bul. 244; Kennard and Chamberlin, Ohio Bimo. Bul. 181; Wightman, West Va. Bul. 298.
126. Fraps, Texas. Bul. 678.
127. Hill, Carter, and Sherwood, Tex. Rpt. 1943.
128. Bohstedt and Lathrop, Wis. Bul. 441; Lathrop and Bohstedt, Wis. Res. Bul. 135; Lindsey and Beals, Mass. Bul. 200; Taylor and Anthony, Mich. Quar. Bul., 17, 1934, No. 1; Olson, S.D. Bul. 281; see also: Berry, Md. Bul. 332; Watson, Muir, Davidson, and Dore, Sci. Agr., Canada, 13, 1933, pp. 382–394.
129. Carroll, Ill. Cir. 414; Carroll and Garrigus, Ill. Rpt. 1933; Evvard, Culbertson, and Hammond, Iowa, mimeo. rpt.; Robison, Ohio Bul. 488; see also: Ferrin, Minn. Pamphlet 21; Weaver, Mo. Bul. 247; Robison, Ohio Bimo. Bul. 134.
130. Fairbanks, King, Gobble, Krider, and Carroll, Ill., Jour. Anim. Sci., 3, 1944, pp. 250–266.
131. Jordan, S.D. Farm and Home Res., 5, 1954, No. 2.
132. Moseley, Stuart, and Graves, U.S.D.A. Tech. Bul. 116; Miller and Graves, U.S.D.A. Tech. Bul. 321; Cunningham, Ariz. Rpt. 1932; Henke, Hawaii, Jour. Agr. Res., 51, 1935, pp. 51–59; Moore, Miss. Rpt. 1927.

CHAPTER XXI

THE OTHER CEREALS AND BY-PRODUCTS

I. Wheat and Its By-products

731. Importance of wheat.—Wheat (*Triticum aestivum*) is second only to corn in importance as a cereal in the United States, but most of it is raised for the manufacture of flour and other human foods. Relatively little of the crop is generally fed to livestock. However, wheat is satisfactory for all classes of stock when properly used, and is equal or nearly equal to corn in feeding value. Wheat has been extensively used for stock feeding in this country when unusually low in price, or when there was a shortage of feed grains and a surplus of wheat. Low-grade wheat, not suitable for milling, is commonly fed to stock.

Though wheat itself is not usually fed to farm animals in this country, the wheat bran and middlings secured in milling wheat rank next to soybean oil meal in tonnage among the by-product stock feeds.

732. Wheat as a feed.—Wheat resembles the other cereals in the general nutritive characteristics which have been discussed in the previous chapter. (**680**) The protein content of wheat varies widely, depending on the climate, the type of wheat, and the soil fertility. Hard spring wheat, chiefly from the northern plains states, has an average of 15.8 per cent protein, and hard winter wheat, chiefly from the southern plains states, an average of 13.5 per cent protein. Soft wheat is much lower in protein. Soft winter wheat from the Mississippi Valley and eastward has an average of only 10.2 per cent protein, and soft wheat from the Pacific Coast states only 9.9 per cent.

The amount of protein in wheat is highly important from the milling standpoint, as it indicates the amount of gluten. Since gluten gives wheat dough the tenacity required in bread making, a high gluten content is desired in flour for this purpose. Much wheat is therefore now sold at the central markets on the basis of certified percentage of protein. For making cakes and pastries, soft wheat is preferred, with its lower protein content.

The protein of the entire wheat grain is of relatively poor quality, although it is superior to that of corn. In wheat bran and wheat germ the protein is of better quality than in the rest of the kernel.

Wheat has about as much nitrogen-free extract (nearly all starch) as does corn, and is only slightly higher in fiber. It has only about 2 per cent fat, in comparison with about 4 per cent for corn. Wheat is fully as digestible as corn, and supplies about as much total digestible nutrients as dent corn of No. 2 grade.

Wheat is low in calcium, having only 0.04 per cent. Its average phosphorus content is 0.39 per cent, which is appreciably higher than that of corn.

Wheat is deficient in vitamin A value and in vitamin D. It is a good source of thiamine but is low in riboflavin, like the other cereals. It is much higher than corn in niacin.

Durum wheat, grown extensively in the western part of the northern plains area, has about the same composition and feeding value as the other spring wheat raised there. The standard weight of wheat per bushel is 60 lbs.

Wheat is usually well liked by stock and is frequently fed as the only grain to swine and to fattening cattle and sheep. However, cattle or sheep occasionally go "off feed" or have digestive disturbances when heavily fed on wheat. This can be avoided by mixing wheat with other feeds, such as corn, oats, barley, or bran.

Since the kernels are rather hard and small, wheat should be ground or crushed for feeding to cattle and horses, and also for swine unless they are self-fed. The grain should be ground to only a medium degree of fineness, for wheat ground to a fine, floury meal is less palatable and more apt to form a pasty mass in the mouth.

Low-grade wheat which is not suitable for milling may nearly equal wheat of milling quality in value for stock feeding, if it is not badly molded. The value of salvage wheat or other salvage grain, which has been damaged in elevator fires, will depend on the extent of injury by charring or smoke.

In using wheat as a feed, the fact that it is higher than corn in protein should be borne definitely in mind. Less protein supplement is needed to balance a ration when wheat is the chief grain than in the case of corn.

733. Wheat for dairy cattle.—Ground wheat is about equal to ground corn for dairy cattle and is an entirely satisfactory feed, even for long periods, if fed in a suitable concentrate mixture and in a properly balanced ration.[1] For dairy cows wheat should be ground, not too finely, or crushed, and it is best to mix it with some bulky concentrate, as it is a very heavy feed. Because of its rather pasty nature, the best results are probably secured when wheat does not form more than one-third to one-half of the concentrate mixture. However, wheat has been fed successfully to cows as the only concentrate, with plenty of legume hay for roughage.

Heads of Different Types of Wheat

From left to right: 1, bearded winter wheat; 2, beardless spring wheat; 3, bearded spring wheat; 4, durum, or macaroni wheat; 5, club wheat.

734. Wheat for beef cattle.—When economical in price, wheat may be substituted for other grain in feeding beef cattle. In several experiments, as mentioned later, ground wheat has given excellent results even when fed as the only grain for fattening cattle. However, in other trials wheat has been much less satisfactory than corn as the sole grain.[2] More care is necessary to prevent cattle fed heavily on wheat from going "off feed" than when other grains are used. Also wheat is somewhat less palatable than corn to cattle.

For these reasons other grains, such as corn, barley, or oats, should, if possible, be mixed with ground wheat for fattening cattle, or else it should be mixed with silage or some other bulky feed. Several experiments have shown that on such mixtures as one-half wheat by weight and one-half of these other grains the gains are generally fully equal to those on corn. Also, the cattle have good appetites throughout the fattening period, are not apt to bloat, and do not tend to go "off feed."[3]

If wheat is fed as the only grain by an experienced cattleman, it may be fully equal to corn in value. In 9 trials in which ground or rolled wheat was thus compared with ground or rolled corn, the wheat-fed cattle made nearly as rapid gains as did those fed corn.[4] In these trials wheat would have produced gains at equal cost, if priced 9 per cent higher per ton than corn.

Ground wheat had a similar high value in 6 trials in which it was compared with ground barley as the only grain.[5] The gains were as rapid on wheat as on barley, and less feed was needed per 100 lbs. gain. On the basis of the feed per 100 lbs. gain, wheat was worth about 18 per cent more than barley.

Wheat should be coarsely ground or else rolled for beef cattle. In tests of these methods of preparing wheat for fattening cattle, there has been no consistent difference in favor of either ground wheat or rolled wheat.[6] In comparing the values of corn and wheat for beef cattle, it should be borne in mind that there is no need of grinding corn if pigs follow the cattle, while wheat is not utilized well unless ground. The cost of grinding must therefore be deducted to find the value of whole wheat per ton, before being ground, in comparison with shelled corn. Sometimes this will be partly offset by the fact that wheat is richer than corn in protein. No supplement may therefore be required with wheat, while it may be needed with corn.

While the results with wheat have differed, it can be concluded that when ground wheat is mixed with other grain for fattening cattle, it is fully equal to corn. Frosted or shrunken wheat may give as good results as wheat of good milling grade.

735. Wheat for sheep.—Wheat is a very satisfactory grain for fattening lambs or for the breeding flock. Although wheat is satisfactory as the only grain for fattening lambs, somewhat better results seem to be secured when it is fed in combination with shelled corn, barley, grain sorghum, or oats.[7] Lambs like such mixtures a little better than wheat alone, and there is sometimes less trouble with them going "off feed."

Wheat fed as the only grain to fattening lambs has produced slightly more rapid gains, on the average, than barley.[8] Also, a little less feed was required per 100 lbs. gain by the wheat-fed lambs, and 100 lbs. of wheat were equal in value to 106 lbs. barley plus 7 lbs. hay.

In experiments in which wheat has been compared directly with corn for fattening lambs, it has had a little lower value than we would expect, in comparison with the results of the tests with fattening cattle and pigs. In 18 experiments lambs fed wheat and legume hay gained an average of 0.28 lb. per head daily, while others fed corn and legume hay gained 0.31 lb.[9] The wheat-fed lambs also required slightly more grain and hay per 100 lbs. gain. Considering only the feed required per 100 lbs. gain and not the difference in rate of gain, 100 lbs. of wheat were equal to 90.6 lbs. shelled corn minus 15.0 lbs. hay. With corn at twice the price of hay per ton, this would make wheat worth 83 per cent as much per ton as corn.

Experiments have shown that it does not usually pay to grind or crush wheat for sheep.[10] Indeed, the ground or crushed grain is less palatable to them and in the case of fattening lambs will usually produce less rapid and less economical gains than whole wheat.

736. Wheat for horses and mules.—Wheat is a satisfactory substitute for oats, if ground coarsely or crushed, and mixed with a bulky feed to prevent colic. Thus fed with care, its value per 100 lbs. will be higher than that of oats.

737. Wheat for swine.—Wheat of good quality is well liked by swine, and is even slightly superior to corn in value for them. It produces firm pork of good quality. In 23 experiments pigs fed ground wheat as the only grain, with an efficient protein supplement, gained a little more rapidly than others fed corn in place of wheat.[11] Because wheat contains more protein than does corn, a little less tankage or other protein supplement was required with wheat, but the wheat-fed pigs consumed a trifle more grain per 100 lbs. gain.

In these trials 100 lbs. of ground wheat were equal in value to 96.8 lbs. shelled corn plus 2.9 lbs. tankage or tankage equivalent. With feeds at representative prices, wheat would be worth about 3 per cent more than shelled corn. In 22 other trials ground wheat has produced slightly more rapid gains than ground barley, when fed as the only grain to pigs, and 100 lbs. wheat have been equal to 107.8 lbs. barley plus 2.1 lbs. tankage or tankage equivalent.[12]

When wheat is fed in self-feeders, pigs chew the grain so thoroughly that grinding it does not usually make sufficient saving to warrant the expense.[13] On the other hand, grinding is advisable when wheat is hand-fed, for the pigs are so eager to get their share that they do not chew whole wheat thoroughly. Wheat should not be ground too finely, or it may form a pasty mass in the mouth. Whole wheat should not be soaked as a substitute for grinding, as it is not so well utilized as the dry whole grain.[14]

Wheat generally gives excellent results when fed as the only grain to swine. Occasionally, however, when wheat is thus fed, pigs may show a little more tendency to go "off feed" than when corn or barley is fed. In such cases, it is well to mix other grain with the wheat, for the combinations produce very satisfactory results. When pigs are self-fed both wheat and corn separately, free choice, they may eat 3 to 5 times as much wheat as corn, because they like wheat so well.[15]

Though wheat is somewhat richer than corn in protein, nevertheless it requires the addition of an efficient protein supplement to produce rapid and economical gains, except for pigs on excellent pasture. Wheat is so palatable to pigs that when they are self-fed, free-choice, on wheat and either tankage or fish meal, they do not generally take more of the supplement than they need.

738. Wheat for poultry.—Wheat is preferred to all other grains by poultry, and it is equal or slightly superior to corn in value for them.[16] Even when wheat is more expensive than other grains, a limited amount is often included in poultry rations because of its palatability and to furnish greater variety.

When wheat is low in price, it can be used satisfactorily as a complete substitute for yellow corn, if sufficient vitamin A is provided by other feeds. Ground wheat may also be substituted for wheat bran and wheat middlings in poultry mashes, but it must be remembered that wheat is lower in protein and also in phosphorus. Soft wheat is somewhat more palatable to poultry than hard wheat, when the whole grain is fed.

If laying hens are self-fed whole wheat, free choice with mash, they may eat so much wheat that they will not consume enough of the mash to balance their ration. This may be avoided by feeding the whole wheat in the evening on top of the mash in about the amount that will be consumed at this feeding.[17]

It has been believed by some that the feeding of new wheat, soon after threshing, tends to produce blue comb, or pullet disease. It is therefore best not to feed wheat to poultry until it has dried out and passed through the sweat.

739. Wheat flour manufacture and the milling by-products.—The wheat kernel is covered with brownish bran coatings, which are richer than the entire grain in protein and minerals and also much higher in fiber. Under the bran is the brownish aleurone layer, also rich in protein. The germ, which is at the base of the kernel, is rich in oil, protein, and minerals. The remainder of the kernel consists of thin-walled cells packed

with starch grains. Among the starch grains are the particles of gluten that give wheat dough its tenacity.

In producing flour the miller desires to secure all the starch and gluten possible from the wheat grains, while avoiding the germ and bran. He leaves out the germs because they make a sticky dough and also soon turn dark and rancid, giving the flour a specked appearance. Nor does he use the aleurone layer, as it gives a brownish tint to the flour.

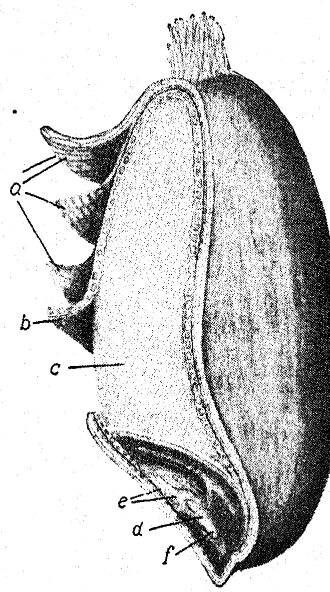


DIAGRAM OF WHEAT KERNEL

A, the bran coats; b, aleurone layer; c, cells filled with starch grains; d, embryo, or germ; e, embryo leaves; f, embryo root.

In modern milling, the wheat is first cleaned and moistened to toughen the bran. Then it passes between pairs of steel rollers, the first pairs of which are corrugated. These rollers gradually break the kernels into pieces, flatten out the bran, and separate the flour from it. After passing through each pair of rollers, the flour is removed by sieves and bolting cloth. Later in the process, the various by-products are separated, all possible flour being recovered at each step in the reduction of the kernels.

The terms used to designate the various by-products differ somewhat in various parts of the country, and also the names of certain of the winter wheat by-products differ from those of the spring wheat by-products. The term *wheat bran* (often called merely "bran") is used for the coarsest by-product, which consists chiefly of the bran layers. For the finer by-products from spring wheat the terms commonly used are *standard middlings, flour middlings,* and *wheat red dog.* In the case of the by-products from winter wheat, the common names are *brown shorts, gray shorts,* and *white middlings.*

In a small proportion of the flour mills, a part of the wheat germ is separated from the other by-products, for the production of wheat germ oil or other purposes. Where part of the germ has been removed, the wheat by-products, especially the middlings, will be lower in vitamin E, and also a little lower in fat.

In the manufacture of white flour, about 71 per cent of the weight of the cleaned wheat goes into the flour and the remainder into the by-products. Of the total by-products, bran and standard middlings each form about two-fifths of the weight, and wheat red dog slightly less than one-fifth.

740. Wheat bran.—Wheat bran, which consists almost entirely of the coarse outer coatings of the wheat kernel, is one of the most popular and important stock feeds. It is highly palatable to stock, and it has a mild laxative effect. Also, it is twice as bulky as oats. Its popularity is due in no small part to these characteristics.

Wheat bran averages 16.4 per cent in protein and 4.5 per cent in fat, and does not usually contain more than about 10 per cent fiber. Wheat bran supplies 66.9 lbs. of total digestible nutrients per 100 lbs., which is slightly less than oats furnish.

The protein of bran is of better quality than that of corn or the entire wheat grain, but it is not so good as the protein in such feeds as soybean oil meal, milk, meat by-products, and fish by-products.

In phosphorus content bran is one of the richest of all common feeds, but

it is low in calcium. It has 1.29 per cent of phosphorus, but only 0.13 per cent of calcium.

Wheat bran has practically no vitamin A or vitamin D. It is rich in niacin and fairly high in thiamine, but rather low in riboflavin, though having more than twice as much as does the whole wheat grain.

The best grades of bran have large clean flakes and contain no screenings. Such bran is often called "pure wheat bran." When bran contains screenings, most states require that the fact be indicated on the feed tags.

"Standard bran," or bran containing screenings, usually sells at 50 cents to $1.00 less per ton than pure bran. Since wheat screenings have much the same chemical composition as wheat bran, there is often no significant difference in composition between bran without screenings and standard bran. Unless bran contains more screenings than usual or unless the weed seeds are of a kind that give it a bitter taste, the difference in price between the two grades probably represents the approximate difference in actual value. However, there may be more danger of introducing noxious weeds on the farm when bran is fed that contains screenings.

Hard spring wheat bran does not differ much in composition from winter wheat bran, but it is slightly higher in fat and furnishes slightly more total digestible nutrients.

Bran and middlings from small mills in which the flour is not separated so completely are a little higher in nitrogen-free extract, a little lower in fiber, and also slightly lower in protein than these by-products from large mills. Such "country mill bran" and "country mill middlings" frequently sell at a slight premium. However, sometimes these terms are used in a misleading manner for any bran or middlings which does not come from a mill in one of the large milling centers.

741. Wheat standard middlings; brown shorts.—*Wheat standard middlings,* usually called "standard middlings" or merely "middlings," are the by-product from spring wheat that consists mostly of fine particles of bran and germ, with very little of the wheat red dog. The similar by-product from winter wheat milling is called *wheat brown shorts,* or sometimes "red shorts." These feeds have about the same composition, except that standard middlings are slightly higher in fiber and also higher in protein and fat than brown shorts. According to the definitions of the Association of American Feed Control Officials, standard middlings must not contain more than 9.5 per cent fiber and brown shorts not more than 7.5 per cent.[18]

Standard middlings are slightly richer in protein and fat than wheat bran and contain more nitrogen-free extract. They are appreciably more digestible than wheat bran and have an average of 77.2 lbs. of total digestible nutrients per 100 lbs. in comparison with 66.9 lbs. for bran. Standard middlings thus supply about 15 per cent more total digestible nutrients and have a correspondingly higher value, except when the more bulky nature and greater laxative effect of bran are desired. Standard middlings are rich in phosphorus, but they are low in calcium, like other wheat by-products.

Middlings supply practically no carotene or vitamin D. They are high in thiamine and niacin, but low in riboflavin.

Standard middlings are used chiefly for swine, calves, and poultry, but may also be fed to other stock in place of bran. For swine and poultry, middlings do not give good results when fed as the only supplement to the grains, because their protein does not correct the deficiencies in the proteins of the grains. Standard middlings and other types of middlings are excellent swine or poultry feeds when part of the protein in the ration comes from such feeds as soybean oil meal, tankage, or dairy by-products.

742. Wheat red dog; wheat white shorts.—*Wheat red dog,* also called "red dog flour," is the spring wheat by-product from the "tail of the mill," consisting chiefly of the aleurone layer, together with small particles of bran, germ, and

flour. The similar by-product from winter wheat is *wheat white shorts,* also called "white middlings." Wheat red dog is slightly higher in protein and fat than white shorts, but otherwise there is little difference in composition.

These by-products are considerably lower in fiber and higher in nitrogen-free extract than standard middlings. They are highly digestible and are even richer than the entire wheat grain in total digestible nutrients. They are fed chiefly to swine, especially young pigs, but are also often used in calf meals, on account of their high digestibility.

743. Wheat feed flour.—Wheat feed flour consists principally of wheat flour, together with fine particles of wheat bran, wheat germ, and the material from the "tail of the mill." According to the definition of the Association of American Feed Control Officials it should not have more than 1.5 per cent of fiber.[18]

744. Wheat flour middlings; wheat gray shorts.—*Wheat flour middlings* consist of standard middlings and wheat red dog combined.

The similar by-product from winter wheat is *wheat gray shorts* (also called "gray middlings" or "total shorts"). The average fiber content of flour middlings is 4.3 per cent and of gray shorts 6.0 per cent. Flour middlings and gray shorts are used much like standard middlings, but are especially well suited to young pigs, because they are slightly higher in digestible nutrients than standard middlings or brown shorts.

745. Wheat mixed feed.—Wheat mixed feed consists of wheat bran and the flour middlings or gray shorts. It is often called "mill run." Since wheat mixed feed of good quality contains the middlings, it is somewhat lower than wheat bran in fiber and it is about 5 per cent higher than bran in total digestible nutrients. This is about the usual difference in feeding value, unless bran is desired for greater bulk.

746. Wheat germ meal; wheat germ oil meal.—Certain of the larger flour mills separate some of the wheat germ more or less completely from the middlings and sell the product as *wheat germ meal.* This contains the germs together with some bran and middlings. It has an average of 27.8 per cent protein and 9.2 per cent fat, and is used chiefly in dog foods, mink feeds, and feeds for laboratory animals. Wheat germ meal is rich in vitamin E. Its use to prevent the "stiff-lamb disease" is discussed in Chapter XXXI.

Sometimes much of the fat is removed from the wheat germs, in the production of wheat germ oil. The by-product which remains is *wheat germ oil meal* or *cake.* This is much lower than wheat germ meal in fat and in vitamin E.

747. Palmo middlings.—"Palmo midds" is a by-product in the making of tin plate. The excess of the palm oil used in polishing the tin plate is removed by scouring the plate with wheat middlings (often containing some screenings). This mixture of middlings with a small amount of oil is sold as palmo middlings.

This by-product usually contains 7 to 10 per cent of fat or oil, and is slightly lower in protein than standard wheat middlings. It should be used in the same manner as wheat middlings in stock feeding and is chiefly fed to swine. On account of the rather high oil content, it had best not form more than 20 to 25 per cent of the ration. Also, palmo middlings may contain appreciable amounts of fine tin particles and may consequently be toxic to stock if it forms a large part of the ration.[19] Smaller proportions of palmo middlings are not injurious.

As a feed for pigs, palmo middlings has generally been worth appreciably less than standard wheat middlings or flour middlings.[20]

748. Wheat by-products for dairy cattle.—*Wheat bran* is one of the most popular dairy feeds, and its value for milk production seems to be somewhat greater than would be estimated from its content of protein and digestible nutrients. Bran is usually fed in combination with the grains and with feeds richer in protein, such as the oil meals. It has a higher value when forming not over one-fourth to one-third of the concentrate mixture than when more is fed. On account of its laxative effect and its bulky nature, bran is especially valuable for

cows just before and after calving and for those on official test. It is also excellent for dairy calves and heifers. Bran and oats are often substituted for each other, wholly or partially, in making up concentrate mixtures for dairy cattle.

Wheat mixed feed may be used in place of wheat bran in dairy rations and is worth about 5 per cent more than bran for this purpose.

Standard wheat middlings or *wheat shorts* are satisfactory for dairy cows when forming not over one-third of the concentrate mixture. Though they are not so bulky as bran or quite so palatable, they are slightly higher in protein and are higher in total digestible nutrients. If standard middlings cost no more than bran, they are an economical substitute for part or all of the bran for dairy cows, unless the bulk of bran is desired to lighten the concentrate mixture.

749. Wheat by-products for beef cattle.—The use of *wheat bran* for beef cattle is limited chiefly to the breeding herd and young calves, and bran is excellent as part of the concentrates for such stock. Bran is also sometimes mixed with the grain when fattening cattle are being started on feed. After the cattle are on full feed, the bran is generally replaced by more concentrated protein supplements, such as linseed meal, cottonseed meal, or soybean oil meal. This is because a much larger amount of bran than of these high-protein feeds must be fed to balance a ration. Since bran is bulky and relatively low in total digestible nutrients, the considerable amount needed to balance the ration will lessen the gains of fattening cattle and result in a poorer finish.[21]

In Kansas experiments with calves or yearling steers being wintered on sorghum silage, nearly 2 lbs. of bran per head daily were needed to produce as good gains as were obtained when 1 lb. of cottonseed meal was fed.[22]

Wheat mixed feed may be used for beef cattle in the same manner as wheat bran. *Wheat middlings* or *wheat shorts* are not commonly fed to beef cattle, but may be included in the ration when economical in price.

750. Wheat by-products for sheep.—*Wheat bran* is excellent as part of the concentrates for breeding ewes, as it is laxative and fairly rich in protein. It is also often used as part of the grain mixture for young lambs, and is frequently mixed with corn and other heavy concentrates in starting fattening lambs on feed. It should form no large part of the grain allowance for fattening lambs after they are on full feed, for it is too bulky.[23] When bran is cheaper in price than grain, 10 to 15 per cent can be satisfactorily included in the mixture for fattening lambs.[24] Such combinations are commonly used in fitting sheep for show.

Wheat mixed feed can be used like wheat bran in sheep feeding. *Wheat middlings* and *wheat shorts* are not often fed to sheep. When standard wheat middlings were fed at the rate of 0.35 lb. daily to fattening lambs in a New York trial, there was a tendency for some of the male lambs to develop urinary calculi.[25] (251)

751. Wheat by-products for horses and mules.—*Wheat bran* is one of the most useful feeds for horses and mules, because of its bulky nature and mild laxative properties. If not more freely provided, its use once a week is desirable. When horses are fed grain as the only concentrate on work days, it is a good plan to feed them on Sundays and other idle days a mixture of one-third bran with two-thirds oats or other grain. Bran is excellent as a part of the ration for brood mares, foals, and stallions. When bran is cheap, it is an economical substitute for part of the grain for work stock.

If horses are constipated, a wet mash may be used, which has a more laxative effect than dry bran fed in mixture with other feed. A wet bran mash is prepared by pouring hot water over the bran and letting it stand for a half hour or more before feeding. A wet bran mash should be given at night and preferably before a day of rest.

Though *wheat middlings* or *shorts* furnish more nutrients than bran, they are not so desirable for horses, because of their heavier character. When fed to

horses, they should be mixed with bulky feeds and should not form over one-fourth the concentrates, as they may tend to produce colic if fed in too large amounts.

752. Wheat by-products for swine.—*Wheat standard middlings* and *brown shorts* are popular swine feeds. They produce excellent results when fed with grain and such protein supplements as dairy by-products, soybean oil meal, meat scrap, or fish meal, which supplement the protein of the grains better. When thus fed, standard middlings are worth fully as much or slightly more than corn per pound. Middlings have the highest value for pigs when not over about 1 lb. per head daily is added to a ration of grain and a high-quality protein supplement.

In 20 experiments in which standard middlings were added to a ration of grain and tankage for pigs in dry lot, the addition of middlings increased the rate of gain slightly.[26] On the average, each 100 lbs. of middlings replaced 88 lbs. of corn and 10 lbs. of tankage. When middlings are added to a ration containing alfalfa hay, grain, and a good protein supplement, the rate of gain is not usually increased.[27]

For pigs on pasture, it does not pay to add middlings to such a ration as corn and tankage, unless the middlings cost considerably less per ton than corn.[28] Middlings produce fair gains when fed to pigs on good pasture as the only supplement to grain, but it usually pays well to add a small amount of a more efficient protein supplement.

Middlings should not be used as the only protein supplement to grain for pigs or breeding swine which are not on first-class pasture. On such a ration the results will be unsatisfactory, because of poor quality of protein. Even when pigs not on pasture are fed alfalfa hay in addition to grain, middlings are not very efficient as the only protein supplement. For example, in 3 experiments pigs fed middlings, alfalfa hay, and corn gained only 0.91 lb. a day, while others fed corn and tankage, with or without alfalfa hay, gained 1.30 lbs.[29]

When middlings are occasionally much lower in price per ton than corn or other grain, they may be used as a grain substitute. However, as they are a less concentrated feed than corn, they produce less rapid gains and are worth only about 85 per cent as much as corn for fattening pigs.[30]

Wheat red dog and *wheat flour middlings* are preferred to standard middlings and brown shorts for young pigs, because of their lower fiber content. Wheat flour middlings are worth 12 to 18 per cent more per ton than standard middlings for growing and fattening pigs.[31] Wheat red dog is probably worth slightly more than wheat flour middlings, because of its greater digestibility.

Wheat bran and *wheat mixed feed* are too bulky for growing and fattening pigs. They are, however, satisfactory as part of the ration for brood sows, and are especially useful, because of their bulk and laxative effect, when no legume hay is available for the sows.

753. Wheat by-products for poultry.—The wheat by-products are popular ingredients of mashes for poultry. Because of the popularity of high-energy poultry rations, wheat bran is now used to lesser extent than formerly, but wheat middlings and red dog flour, which are higher in net energy, are used instead. Including wheat feeds in the ration tends to produce more rapid growth and development and better feathering of growing chickens.[32] Wheat feeds help supply B-complex vitamins, including the vitamins necessary, in addition to manganese, for the prevention of perosis, or slipped tendon, in chickens.[33]

Wheat bran is often used in poultry mashes, especially for laying hens. Usually not more than 10 per cent is included in a laying mash.

Wheat standard middlings and *wheat flour middlings* are common ingredients of poultry mashes, both for laying hens and for chicks, the amount usually being limited to no more than 10 to 20 per cent of the mash. Wheat flour middlings are worth somewhat more than standard middlings, because of their higher net-energy content.

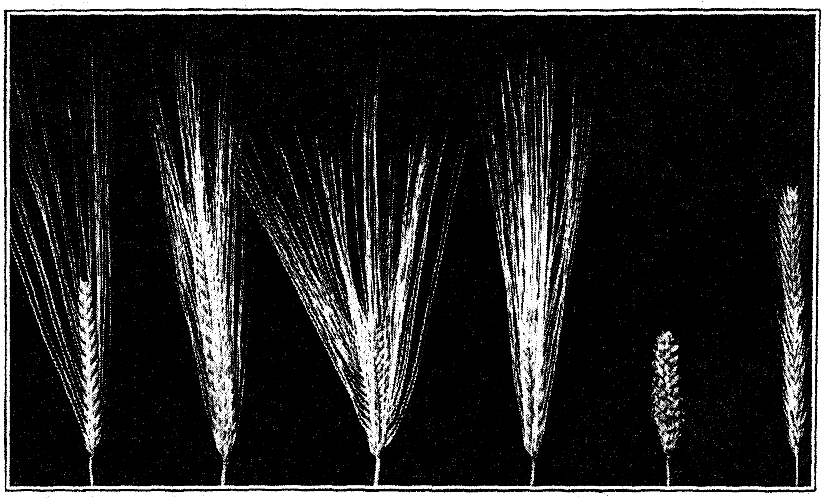
II. Barley and Its By-products

754. Importance of barley.—Barley, which ranks fourth in importance as a grain crop in the United States, is the most widely cultivated of the cereals throughout the world. The crop is especially well adapted to regions of cool summers where the soil is not too sandy but is well drained. It is especially suited to sections with rather scanty rainfall and short growing seasons. Barley does not thrive in a hot, humid climate, and spring barleys therefore do not do well in the southern part of the corn belt.

Barley holds first rank in acreage among the cereals in California, and it is of much importance in the entire district from Minnesota westward to the Pacific Coast. Winter varieties of barley are less hardy than winter wheat and are therefore not suited to cold winter climates. As winter barley matures before the midsummer heat, it does well south of the area where spring barley thrives.

The development of high-yielding smooth-awned varieties of barley by the experiment stations has removed from harvesting barley much of the disagreeableness caused by the barbed beards of the older varieties. In growing barley one should be sure that he has a variety that is well adapted to his locality, for the results from any variety differ widely in various sections. Where barley stripe is a serious disease, it is important to grow a resistant variety.

Often a combination of barley and oats will produce a greater weight of grain per acre than either crop grown alone. The combination is therefore extensively raised in some localities, when the grain is intended for stock feeding and not for market.



Heads of Different Varieties of Barley and of Rye

From left to right; 1, two-rowed barley; 2, common six-rowed barley, or so-called four-rowed barley; 3, true six-rowed barley; 4, California feed barley; 5, beardless barley; 6, rye.

755. Barley as a feed.—Barley is a little higher than oats in protein content, averaging 12.7 per cent except in the Pacific Coast district, where the protein is lower. In certain areas of the northern Plains States and western Canada, the protein content of barley grown without irrigation is appreciably higher than in other districts. For malting, barley medium to low in protein is preferred, but for stock feeding high-protein barley needs less protein supplement.

The hulls form about 15 per cent of the usual types of barley, the best grades of which weigh 46 lbs. or more per bushel. (The legal weight of barley

per bushel in most states is 48 lbs.) Because of the hulls, common barley averages 5.4 per cent in fiber content.

Barley supplies considerably more total digestible nutrients per 100 lbs. than oats and slightly less than corn. Some of the barley varieties grown in the West have thicker hulls and are therefore lower in digestible nutrients and feeding value. Light-weight barley is worth considerably less than heavy, plump barley, as it contains a larger proportion of hull.

Winter barleys and the ordinary spring barleys apparently have about the same composition and value. Hull-less barley resembles wheat or rye in composition, as the hulls do not adhere to the kernels of the threshed grain. However, the yield is considerably less than for the ordinary varieties of barley.

Barley has the same nutritive deficiencies as the other cereals, which have been discussed in the previous chapter. (**680**) The protein is not of good quality, though it is of somewhat better quality than that of corn. Barley lacks carotene and vitamin D and is low in riboflavin. It is rich in niacin, having about 3 times as much as does corn.

Barley should be ground, or crushed, except for sheep or when fed with whole grain to poultry.

Occasionally, cattle bloat when fed barley as the only or the chief grain, especially when the roughage is alfalfa hay. However, the trouble from this source is ordinarily not serious, and it can be avoided by mixing ground barley with ground corn or oats.

Scabbed barley has no injurious effect on cattle, sheep, or poultry, but should not be used for horses or swine. (**672**)

756. Barley for dairy cattle.—Ground or crushed barley is an excellent feed for dairy cattle. When forming from 40 per cent to as much as 60 per cent of the concentrate mixture for dairy cows, ground barley has been equal to ground corn in Arizona, Michigan, North Dakota, and Wisconsin experiments.[34] Some farmers believe barley tends to dry up cows, but there is no evidence at all for this opinion.

Barley should be ground to a medium fineness or crushed for dairy cattle.[35] Too fine grinding is undesirable, as finely ground barley may become pasty in the mouth and consequently unpalatable.

757. Barley for beef cattle.—In those sections of the western and northern states where corn does not thrive, barley is of great importance in beef production. Numerous experiments have shown that fattening cattle will usually make as rapid gains on ground barley, fed as the only grain, as on shelled or ground corn.[36] However, the cattle fed barley have usually sold for a trifle lower price. Also, when pigs follow the cattle, considerably more pork is produced on the shelled corn ration.

Considering all these factors, ground barley has been worth 88 per cent as much as shelled corn for fattening cattle in 14 experiments. The cost of grinding barley must be deducted from this value of ground barley, to find the relative value of whole barley (to be ground before feeding) in comparison with that of corn. If the cattle are not sold on a discriminating market and if no pigs follow the cattle in the feed lot, then ground barley will be worth as much per ton as shelled corn.

Though barley usually gives entirely satisfactory results when fed as the only grain to fattening cattle, sometimes they tire of it during a long fattening period. Also, there is sometimes a tendency for cattle to bloat when fed barley as the only grain, especially with alfalfa hay as the roughage. In either of these conditions it is wise to mix corn or ground oats with the barley. Except in such instances, there is generally no advantage in mixing oats with barley for fattening cattle, after they are on full feed, unless the cost of oats per ton is considerably less than that of barley.

In a Nebraska trial ground barley was fully equal to ground corn for wintering beef calves, and in a Texas experiment ground barley was superior to corn-and-cob meal for fattening cattle.[37]

Barley should be ground medium-fine or rolled for beef cattle. In Arizona tests it was concluded that steam-rolled barley was slightly superior to ground barley, especially for cattle fattening on a heavy allowance of grain.[38]

Trebi barley and ordinary barley were about equal in value in North Dakota tests.[39] Ground hull-less barley is about equal to ground wheat for beef cattle.[40]

758. Barley for sheep.—Barley is a very satisfactory grain for growing and fattening lambs and for breeding ewes, and it is used extensively for them north of the corn belt and in the range districts of the West. Numerous experiments have shown that fattening lambs fed whole barley will gain nearly as rapidly as those fed corn, but they require somewhat more grain and hay per 100 lbs. gain.[41] On the average, good-quality barley has been worth 87 per cent as much as shelled corn in these experiments. Because the rate of gain is a little less rapid on barley than on corn, it will usually take lambs fed barley 3 to 6 days longer to reach a certain degree of fatness.

Although barley contains somewhat more protein than corn, it is relatively low in it, and therefore the ration should be balanced by feeding legume hay or by adding a protein supplement. It is not generally profitable to add a supplement to a ration of barley and legume hay for fattening lambs, for the ration already has enough protein to produce rapid gains.

Barley produces about as satisfactory results when fed as the only grain as when it is fed in combination with corn to fattening lambs. Numerous experiments have shown that for fattening lambs or for breeding ewes it does not usually pay to grind or roll barley, with the possible exception of the hard bald or hull-less barley. Fattening lambs fed ground or rolled barley have usually gained less rapidly and required slightly more feed per 100 lbs. gain than those fed the whole grain.

759. Barley for horses and mules.—Barley is a very satisfactory grain for horses and mules when properly fed.[42] It should be crushed or ground (not too finely). Also, as it is much heavier than oats, it should be mixed with some bulky feed, such as 15 per cent or more of wheat bran or chopped hay, or 25 per cent of ground oats, to avoid danger of colic. Crushed or ground barley is worth about 10 per cent more than crushed or ground oats for feeding work horses, but whole barley is worth less per pound than oats, because horses do not chew the grain completely.

760. Barley for swine.—Barley is an excellent grain for swine feeding and produces pork of high quality, the fat being hard and firm. It should be ground or crushed for swine. In numerous experiments ground barley, fed in properly balanced rations, has produced nearly as rapid gains as corn. However, since barley is less concentrated than corn, because of the hulls, the pigs fed barley require somewhat more feed per 100 lbs. gain. On the average, ground barley of good quality has been worth about 91 per cent as much as corn in these trials. Considering the cost of grinding (which is not necessary in the case of corn), whole barley is worth about 81 to 85 per cent as much per ton as corn for pigs. It is not necessary to mix barley with other grain to secure good results in swine feeding.

Since barley is richer than corn in protein, less protein supplement is needed with barley than when corn is fed. However, pigs that are self-fed, free-choice, on barley plus tankage or other protein supplements often eat decidedly more of the supplement than is needed to balance the ration. It is therefore best to mix the proper proportion of supplement with the ground barley and then self-feed the mixture, instead of self-feeding the grain and supplement separately. Suitable mixtures for dry lot and pasture feeding are shown in Appendix Table VII. Whether or not to feed a protein supplement to pigs fed barley on first-class pasture is discussed in Chapter XXXIV.

The value of barley for growing and fattening pigs is shown by the results of

32 experiments, in each of which one lot of pigs was fed good-quality barley and another lot corn, both lots receiving in addition an efficient protein supplement.[43] In this summary experiments have not been included where the pigs ate an excess of supplement when it was fed free-choice, or where the experimenters fed considerably more supplement than was needed to balance the ration. If just as much supplement is fed with barley as with corn, advantage is not taken of the fact that barley contains more protein than does corn.

On the average, the pigs fed barley gained 1.50 lbs. a day, in comparison with 1.58 lbs. for those fed corn. For each 100 lbs. gain, the barley-fed pigs required somewhat more grain than the corn-fed pigs, but a trifle less supplement (most of which was tankage or meat scrap). In these trials 100 lbs. of ground barley were equal in value to 87.7 lbs. corn plus 2.1 lbs. tankage or tankage equivalent. With feed at representative prices, ground barley would be worth about 91 per cent as much as corn, so far as amount of feed required per 100 lbs. gain was concerned. In 14 similar trials with pigs on pasture, ground barley has likewise been worth about 91 per cent as much as corn.[44] For pigs fed for bacon production in Canadian experiments ground barley had a higher value than this in comparison with corn imported from South Africa. However, no more protein supplement was fed with corn than with barley, and the gains on the corn rations may have been lowered somewhat by a lack of protein.[45]

The saving made by grinding or crushing barley for growing and fattening pigs has differed considerably in various tests, but in nearly all cases it paid to grind or crush the grain. In 29 experiments grinding barley has increased its value 18 per cent on the average.[46] It is best to grind barley to at least a medium degree of fineness, instead of merely cracking it. Very fine grinding does not probably cause sufficient additional increase in value to warrant the greater cost. The pelleting of ground barley is discussed in Chapter XXXIV. (1437)

When barley cannot conveniently be ground, it is often soaked for 12 hours or more before feeding it, but this is a poor substitute. Soaking the grain may produce somewhat more rapid gains, but usually there is little or no saving in the feed required per 100 lbs. gain.[47]

Light-weight barley is worth less than plump, heavy barley, because of the larger proportion of hulls.[48] Trebi barley and the Manchurian varieties have about the same value for swine feeding.[49] Hull-less barley resembles wheat in feeding value.[50] Barley that is badly affected with scab is unsuited for swine. (672)

761. Barley for poultry.—Barley can be substituted for corn or wheat in poultry feeding with satisfactory results, but its value per 100 lbs. is somewhat lower, because of the higher fiber content. In a California trial with pullets the egg production was as high on an all-mash ration containing 68 per cent ground barley as with the same percentage of ground corn, and about the same amount of feed was required per dozen eggs.[51] However, the pullets did not gain as much in weight on the barley ration. In Arizona tests appreciably more feed was required per dozen eggs on a ration having 40 per cent barley than on a similar ration with corn.[52] Fraps of the Texas Station rated barley as having 75 per cent as high a net-energy value as No. 2 corn for chicks.[53]

Since barley lacks vitamin A value, care must be taken to provide a plentiful supply of the vitamin when barley is used to replace yellow corn. Barley produces lighter-colored yolks of eggs than corn and also lighter-colored shanks, skin, and body fat.

Barley is generally rated as being somewhat less palatable than wheat or corn to poultry, but they soon become accustomed to it. When barley is included in the mash it should be ground finely.

Because of the hulls, the growth of chicks is decreased if more than 30 per cent of ground barley is used in a chick starter and more than about 15 per cent in a ration for broilers.[54] Including a large proportion of ground barley in the

mash for baby chicks may cause compaction in the intestines and death losses.

762. Brewery by-products.—In producing beer, the barley is first malted by soaking it in warm water for 2 to 3 days, and then removing it from the water and allowing it to sprout. In this process the amount of diastase, an enzyme that changes starch to malt sugar, increases greatly and some of the starch in the grain is changed to sugar. After sprouting sufficiently, the grain is dried and the small, shriveled roots are separated from the grains. These roots form the feed known as *malt sprouts*. The remainder, consisting of the germinated kernels, forms malt.

The malt is now crushed, water is added, and the mass is kept at the proper temperature for the diastase to change the starch to sugar. Often other grain is added after it has been cooked to gelatinize the starch. When most of the starch has been converted into sugar, the sugar and other soluble matter are extracted to form "wort." This is boiled with hops and filtered, and then yeast is added and the fermentation proceeds.

The residue left after the wort is extracted is called *wet brewers' grains*. These are usually dried and sold as *brewers' dried grains* or *dried brewers' grains*. The spent hops, after drying, are sometimes used in mixed feeds, but have only a low feeding value. The yeast that develops in the fermentation process is sometimes recovered, dried, and sold as *brewers' dried yeast*. (957)

763. Brewers' dried grains.—Brewers' dried grains, often called merely "brewers' grains," contain an average of 27.5 per cent protein, 6.5 per cent fat, 14.2 per cent fiber, and 41.1 per cent nitrogen-free extract. The nitrogen-free extract is largely pentosans, for most of the starch is removed during the malting and extracting process.

Brewers' grains furnish 22.0 per cent digestible protein, but they are rather low in total digestible nutrients, having only 67.1 per cent. They equal corn gluten feed in content of digestible protein but supply considerably less total digestible nutrients. Brewers' grains have decidedly more digestible protein than does wheat bran and equal bran in total digestible nutrients.

Brewers' grains are not very palatable to stock, and therefore they should be mixed with better-liked feeds. They are nearly as bulky as wheat bran, and they keep fairly well in storage.

Brewers' grains are fed chiefly to dairy cattle, especially dairy cows, and produce good results when forming not over about one-third of a concentrate mixture which consists mostly of well-liked feeds. Because of their high fat content, they help to supply the amount of fat that is desirable in dairy rations. (**1020**)

Except when protein supplements cost no more than carbohydrate-rich feeds, brewers' grains are worth somewhat more than wheat bran for dairy cows, because of their higher protein content.[55] On the other hand, they are less valuable than corn gluten feed. In a Pennsylvania test, brewers' grains containing not more than 6 per cent of spent hops were practically equal in palatability and value for dairy cows to brewers' grains containing no spent hops.[56]

In addition to the use of brewers' grains as a protein supplement, they may be used to replace part of the grain in rations for dairy cattle, beef cattle, sheep, and horses, if they are decidedly lower in price per ton than grain. Fattening lambs fed a mixture of one-third brewers' grains and two-thirds shelled corn in 3 New York trials gained as rapidly as others fed corn supplemented with a mixture of linseed meal and cottonseed meal.[57] The brewers' grains saved sufficient corn and supplement to be worth about 98 per cent as much as shelled corn. When only enough brewers' grains were fed, along with corn, to balance the ration, the results were also excellent, and the brewers' grains were worth about three-fourths as much as the mixture of linseed and cottonseed meal.

In an Illinois test, when fattening calves were fed 3.0 lbs. of dried brewers' grains per head daily as a substitute for all the soybean oil meal and some of the

corn in a ration, the gains were slightly reduced.[58] In this test brewers' grains, thus fed, were worth only 55 per cent as much as corn.

Brewers' grains are sometimes an economical substitute for part of the oats in horse feeding, being about equal to oats per pound.[59] Because of their bulkiness, brewers' grains are not usually fed to swine. Even 20 per cent of brewers' grains in the ration for pigs has not given good results.[60]

764. Wet brewers' grains.—Because of their watery, perishable nature, wet brewers' grains are usually fed near the brewery. They are commonly sold by the bushel, as the value per ton varies widely, depending on how well the water has drained out. A bushel of wet grains is equal to about 11 to 13 lbs. of the dried grains. In general, it will take nearly 4 lbs. of the wet grains to equal 1 lb. of dried grains.

To avoid spoilage it may be necessary to haul the wet grains from the brewery every day or two in summer and twice a week when cooler. They may be kept longer by storing in tight barrels, tanks, or pits. Each layer should be tramped thoroughly and sprinkled with salt at the rate of about 1 lb. per 100 lbs. In feeding the wet grains, the mangers and containers should be kept clean and free from any spoiled material.

Wet brewers' grains may be fed to dairy cows at the rate of 20 to 30 lbs. per head daily to replace an equal weight of silage, or as a substitute for part of the concentrates (at the rate of 4 lbs. of the wet grains for 1 lb. of the concentrate mixture). To avoid any tainting of the milk, they should be fed after milking, rather than before, and they should not be stored in the stable. The wet grains may also be fed to other classes of stock, as in the case of the dried grains.

765. Malt sprouts.—Malt sprouts are similar in composition to brewers' dried grains, except that they have much less fat. They are about as bulky as brewers' dried grains, and they supply slightly more total digestible nutrients. Malt sprouts are somewhat bitter and are unpalatable if fed alone. Doubtless for this reason, they are used mostly as an ingredient in mixed feeds, especially for dairy cattle. They are entirely satisfactory for this purpose when used in moderate amounts and are often an economical source of protein and total digestible nutrients. Malt sprouts are often included with the brewers' dried grains, and the mixture sold as brewers' dried grains. The malt sprouts will form only about one-tenth of such a mixture.

Because of the lack of palatability, it is preferable not to include more than about 10 to 15 per cent of malt sprouts in a concentrate mixture for dairy cows or other stock. Feeding too large an amount to dairy cows is said to give the milk a bitter taste. Since malt sprouts swell greatly when they absorb water, they should be soaked for several hours before feeding, if cattle or horses are given more than 2 lbs. per head daily.

In Europe horses are sometimes fed as much as 6 lbs. of malt sprouts per head daily; cattle, 3 lbs.; and sheep, 0.75 lb.

In recent Canadian trials including malt sprouts in a ration for growing pigs increased the rate of gain and decreased the amount of feed required per 100 lbs. gain.[61]

766. Spent hops.—The spent hops, left after the wort has been boiled with hops and filtered, are sometimes dried and used for feed or for fertilizer. They contain not only the hop residue, but also some protein precipitated from the wort in the boiling process. Though they have 20 per cent of protein or more, the digestibility of the material is so low that the product is of doubtful value as a feed.[62] Also, the spent hops are bitter and unpalatable to stock and therefore only a small proportion can be included in a mixture of better-liked feeds.

767. Barley feed; barley mixed feed; barley hulls.—In the manufacture of pearled barley for human food, *barley feed* is secured as a by-product. This consists of the hulls and the outer coats of the kernels. A by-product called *barley mixed feed*, which has about the same composition, is secured when barley flour is manufactured. This should contain not only the hulls but also all the middlings from the kernels. Usually there is but a very small amount of these feeds available in this country. A good grade of barley feed, containing 11 per cent fiber, was worth nearly as much as wheat bran for dairy cows in a Wisconsin trial.[63] For fattening pigs, barley feed was worth 17 per cent less per ton than ground barley.

Barley hulls, sometimes erroneously called barley bran, consist almost entirely of the hulls. Barley bran containing 27 per cent fiber was worth only two-thirds as much per ton for dairy cows as wheat bran in another Wisconsin trial.

768. Malted barley.—It was once believed that the malting of barley increased its value for feeding. Early experiments showed,

however, that a given weight of barley is worth more than the amount of malt and malt sprouts that can be made from it.[64] This is because of the loss of nutrients in the steep water and in the oxidation of nutrients in the germinating process. The use of malt for stock feeding has therefore been practically discontinued, except that malted barley is occasionally used in calf meals or as an appetizer in fitting stock for show.

III. Rye and Its By-Products

769. Rye in the United States.—Though rye (*Secale cereale*) is one of the chief cereals of northern Europe, it is not grown extensively in this country, except in the northern plains. Though it repays good treatment, rye does better than the other cereals on poor or very sandy land.

Practically all the rye grown in the United States is winter rye, which is even more winter-hardy than wheat. In tests in certain districts of the northernmost states, winter rye has led the cereals in average weight of grain produced per acre, even on good soil.

As a winter cover and pasture crop, rye is often grown in certain sections of the South and to a lesser extent in other districts. Its value for pasture during the fall, winter, and early spring has been discussed in Chapter XVIII. (583)

770. Rye for stock feeding.—Rye grain is raised chiefly for bread-making in Europe and is also used largely for this purpose in this country. However, a considerable part of our crop is fed to livestock.

Considering only its chemical composition, we should expect rye to equal wheat in feeding value, for the composition of these grains is very similar. However, even when rye is not appreciably contaminated with ergot, it is usually less palatable to stock than the other grains. Also, when fed as the only concentrate or in too large amounts, it is more apt to cause digestive disturbances.

Rye should therefore be fed with due care and preferably as only part of the concentrates. The grain should not be fed until it has conditioned, or passed through the "sweat" when stored after threshing. Rye that is appreciably contaminated with ergot is unpalatable to stock, and it may even be dangerous if it contains too much of this poisonous substance.

Rye is nearly as heavy a grain as wheat, the weight per bushel being about 56 lbs.

For dairy cows rye had best form not more than 40 to 45 per cent of the concentrate mixture. Thus fed, ground rye has been equal or nearly equal to ground barley or ground corn.[65] Large allowances produce a hard, dry butter, but the butter was satisfactory in a Montana trial when rye formed 40 per cent of the concentrate mixture.[66] Rye should be ground, not too finely, or crushed, for dairy cows.

Though ground rye has given good results in some trials when fed as the only grain to fattening cattle, it is preferable to mix it with corn, oats, or barley. Steers fed ground rye and alfalfa hay in 4 experiments gained nearly as rapidly as others fed shelled corn and alfalfa hay.[67] On the basis of the amount of feed for 100 lbs. gain, rye was fully equal to corn. Like wheat, rye should be ground coarsely or rolled for beef cattle.

Rye is apparently liked better by sheep than by most other stock. When fed as the only grain to fattening lambs, it has produced as good results as barley or wheat in Minnesota and Nebraska tests.[68] Feeding rye as the only grain gave about as good results as using a mixture of half rye and half barley, corn, or oats. There is no advantage in grinding rye for sheep.

Rye is apt to cause digestive disturbances if fed as the only grain to horses, or if the change to rye is made abruptly. It is satisfactory for horse feeding when it forms not more than about one-third of the concentrate mixture and if mixed with oats or some other bulky feed. Rye should be crushed or ground coarsely for horses.

The results secured from rye in swine feeding differ widely.[69] Sometimes pigs make good gains when fed ground rye as the chief grain, but often rye produces poor results, especially with young pigs, when it forms most of the ration. When pigs do well on rye, the feeding value of rye is about equal to that of barley, and the quality of the carcasses is good.

Because of the poor results that are often secured when rye is fed as the only grain, it had best be mixed with at least an equal weight and preferably a larger proportion of other grain, such as corn, barley, oats, or wheat. Rye gives more uniformly good results when fed to pigs on pasture than to those in dry lot. Adding well-cured alfalfa hay to the ration of rye-fed pigs in dry lot is beneficial. A protein supplement should be fed to balance the ration when rye is the chief grain, except perhaps for pigs on good pasture which are over 75 to 100 lbs. in weight. Unless the cost of grinding is unusually high, it pays to grind rye for swine. Rye should be avoided in feeding pregnant sows.

The unsatisfactory results sometimes reported with rye for swine feeding may have been due in some cases to ergot in the rye. However, poor results have been secured even when rye contained no appreciable amount of ergot. Swine have a pronounced dislike for rye that has any marked amount of ergot and eat much less of it than they would otherwise.

Rye is not commonly fed to poultry, as the other grains are more palatable and otherwise superior. Also, rye is too laxative when it forms a large part of the ration. However, rye is usually satisfactory for growing pullets and laying hens if it forms not more than about 20 per cent of the ration.[70] It is best to include the rye in ground form in the mash, because whole rye is not palatable to chickens.

Rye should not be used for chicks during the first week. After this, 5 per cent of ground rye can be included in the mash, and the proportion increased gradually up to 20 per cent by the seventh week. If much rye is fed to chicks, the droppings become so sticky that they ball up on the toes.

771. Rye feed; rye middlings.—All the by-products obtained in the milling of rye for flour are usually combined and sold as *rye feed* or sometimes as *rye middlings,* instead of being marketed separately as bran, middlings, and red dog flour. Apparently, there is little difference between the feeds now sold in this country as rye feed and as rye middlings.

These rye by-products are lower than standard wheat middlings in protein. They furnish slightly less total digestible nutrients than do standard wheat middlings, but somewhat more than wheat bran. They are, however, less palatable than wheat bran, and hence should be mixed with better-liked feeds. For dairy cows, beef cattle, sheep, or swine these rye by-products are a satisfactory partial substitute for wheat bran or wheat middlings, but the amount had best be limited to 15 to 25 per cent of the concentrate mixture. They can also be used to the extent of about 20 per cent in mashes for pullets or hens.

IV. The Sorghums

772. Grain sorghums.—It has already been pointed out in Chapter XVII that in the Plains States from southern Nebraska south to Texas, New Mexico, and Arizona, the sorghums (*Sorghum vulgare*) are of great value for grain and also forage. In the portions of this great area where the rainfall is scanty, they largely take the place of corn, because they are much more drouth resistant. The various types of the sorghums, both the grain sorghums and the sweet sorghums, have been previously described, and their special advantages for grain or for forage pointed out. (543)

As stated previously, the sorghums now grown for grain in the sorghum belt are mostly dwarf combine varieties, which can readily be harvested with a combine. Most of these dwarf varieties were developed by crossing milo with kafir or other taller grain sorghums. Kafir and hegari are also raised for grain to some extent, and sometimes other grain sorghums are grown.

Atlas and certain other crosses between grain sorghum and sweet sorghum are used both for forage and for grain.

Throughout the western portion of the sorghum belt, the grain sorghums are much surer crops than corn, because of their drouth-resistance. Here they usually give decidedly higher yields than corn. In central and eastern Kansas and Oklahoma, the sorghums are superior to corn on poor, thin uplands. Even on the better land in the eastern part of the grain-sorghum belt, it is advisable to use the sorghums as a partial substitute for corn, as insurance against drouth.

The average yield of the grain sorghums in the United States during recent years has ranged from more than 20 bushels per acre to 11 bushels, depending on the rainfall. Yields of 50 bushels or more per acre are sometimes secured under very favorable conditions.

Very recently, hybrid grain sorghums have been developed from inbred strains, somewhat similar to the production of hybrid corn. These new hybrids seem to excel in yield of grain.

The customary basis for selling the seed of the grain sorghums is by the 56-lb. bushel, but the usual weight is about 54 lbs. Grain sorghum heads commonly yield from 70 to 75 per cent of grain on threshing, and it requires 75 to 80 lbs. of sorghum heads to make a bushel of threshed grain. Although the percentage of grain in the entire crop

varies widely with the season and the thickness of the stand, about 30 per cent of the weight of well-cured grain sorghum plants will be grain, on the average. In the case of the dwarf varieties, over half the dry weight may be grain.

When cut for grain, sorghum should not be harvested until the seeds are well matured. Because the hard-coated seeds when apparently dry may contain much moisture, the grain sorghums are especially apt to heat in the bin, unless the grain is well dried.

A Fine Field of Kafir

Because of their resistance to drouth, the grain sorghums are of great importance in regions of low rainfall.

773. Grain sorghums as feeds.—The grain sorghums resemble corn grain in composition and in feeding value. Like corn, they contain about 70 per cent nitrogen-free extract, which is nearly all starch, and they are low in fiber and rich in total digestible nutrients. Most of the grain sorghums have somewhat more protein than does corn, but they have considerably less fat.

The grain sorghums have the same nutritive deficiencies as the other grains. The protein is not of good quality; they are very low in calcium, and they lack vitamin D. Even the yellow-seeded grain sorghums are deficient in carotene. Sorghum grain has about the same content of B-complex vitamins as corn, but it has much more niacin, being as rich as wheat.

When properly supplemented, the grain sorghums are excellent for all classes of farm animals. They are well liked by stock, though they are sometimes slightly less palatable than corn. The seeds of darso, shrock, and sagrain, which are hybrids between grain sorghums and sweet sorghums, are somewhat bitter, due to a high content of tannin. Nevertheless, they give good results when fed to stock.

The seeds of grain sorghums are so small that the grain should be ground for cattle or horses. Otherwise, a considerable percentage will escape mastication. The ground grain is usually called "chop." Grinding for sheep is not necessary, and there is but a small saving in grinding grain sorghum for swine when the grain is fed in a self-feeder on a suitable platform.

Sometimes the unthreshed heads are fed, or the forage, including the heads.

Sorghum head chops, obtained by grinding the entire heads, resembles corn-and-cob-meal in composition and value.

774. Grain sorghum for dairy cattle.—Ground grain sorghum is approximately equal to ground corn for dairy cattle.[71] The ground threshed grain may be fed, or else the entire heads may be ground. Kansas tests show that when whole sorghum grain is fed to cows, one-half or more of the seed may pass through unchewed and hence undigested.[72]

775. Grain sorghums for beef cattle.—In the sorghum belt the grain sorghums largely take the place of corn for beef cattle. Grain sorghum is well liked by fattening cattle, produces nearly as rapid gains as does corn, and is not far below corn in feeding value. Grain sorghum is usually fed to beef cattle either as the ground threshed grain, or as sorghum head chops.

Several experiments have shown that for beef cattle ground grain sorghum is usually worth about 90 to 95 per cent as much as corn. The different varieties of grain sorghum now generally grown do not differ much in feeding value, though the value of milo and the milo-like hybrids is apparently slightly higher than that of kafir or Early Kalo, and appreciably above that of darso.[73]

In Kansas trials with fattening cattle grain sorghum ground to a coarse, mealy texture was utilized slightly better than that ground very coarsely.[74] Rolled sorghum grain was not superior to the ground grain. In 3 Texas experiments with fattening calves, the combined gains of the calves and the pigs following them were fully as large when unground milo was fed, as when the grain was ground.[75] This may have been because the seeds of milo are larger than those of some of the other sorghums.

Sorghum head chops are about equal to ground snapped corn (including husks) in value for fattening cattle and produce nearly as rapid gains as ground threshed sorghum.[76] If one wishes to have the cattle gain as rapidly as possible, it may be best to change to ground threshed sorghum during the latter part of the fattening period.

In Texas experiments there was a greater tendency for urinary calculi to develop in steers fed milo head chops than when fed ground threshed milo.[77]

776. Grain sorghums for sheep.—Experiments have shown that the threshed grains of the various grain sorghums are about equal to shelled corn in feeding value for fattening lambs.[78] Also, there has been no appreciable difference in the value of the different kinds of grain sorghum.

In most of the experiments on grinding grain sorghum for sheep, such preparation has not paid.[79] However, in recent Kansas and Texas trials there has been a slight benefit in grinding or rolling milo or other combine-type grain sorghums for fattening lambs.[80]

Unthreshed sorghum heads have proved equal to the threshed grain in feeding value, considering the actual amount of grain contained, and have produced practically as rapid gains on fattening lambs.[81] In wet weather there may, however, be considerable waste in feeding the unthreshed heads outdoors.

It was concluded in Kansas tests that lambing down a field of ripe grain sorghum is a wasteful practice, if the yield of grain is sufficient to warrant harvesting it.[82] In South Dakota trials, grain sorghums did not produce as much gain per acre when lambed down as did corn.[83]

777. Grain sorghums for horses and mules.—In the regions where they flourish, the grain sorghums are used extensively for feeding horses and mules, and are only slightly less valuable than corn. Sorghum grain should be ground or crushed for horses or mules, and if possible mixed with wheat bran or middlings, for it tends to produce constipation. The grain sorghums may also be fed unthreshed in the heads, or along with the forage.

778. Grain sorghums for swine.—The grain sorghums are excellent for swine and nearly equal corn in feeding value, both for fattening pigs and for

breeding stock. The pork produced by feeding the grain sorghums is equal to that from corn in quality. Numerous experiments have shown that the chief varieties of grain sorghum produce about as rapid gains as corn and the feeding values are about 90 to 95 per cent of that of corn.[84] Sweet sorghum seed and some hybrids which are high in tannin content are less palatable and have less value.

In using grain sorghum as a substitute for yellow corn in swine feeding, it must be borne in mind that sorghum grain does not supply carotene (vitamin A value). Also, milo has even less lysine than does corn. This lack is corrected when it is fed with such protein supplements as soybean oil meal, meat scrap, tankage, or fish meal, which have good supplies of this essential amino acid.[85]

Since grain sorghum has the same nutritive deficiencies as the other small grains and also white corn, brood sows are unable to produce thrifty pigs when fed grain sorghum alone, without a proper supply of protein, minerals and vitamins.[86]

The sorghums should be threshed for swine, instead of being fed in the head.[87] Grinding the heads is a disadvantage, as it forces the swine to eat the fibrous stems of the heads. Also, soaking the heads is inadvisable.

When growing and fattening pigs are self-fed, grinding grain sorghum does not usually increase its value enough to justify the expense.[88] On the other hand, when the grain is hand-fed the pigs are in such haste to get their shares that they do not chew it so thoroughly. Therefore, grinding the grain is then usually advisable. There is no advantage in soaking either whole or ground grain sorghum for swine.

Sometimes ripe grain sorghum is hogged down by turning fattening pigs into the field to harvest the crop. The same methods should be followed as in hogging down corn.[89] **(704)** It may be necessary to restrict the area in which the pigs are feeding, by temporary fencing to get them to clean the grain up properly.

779. Grain sorghums for poultry.—The grain sorghums are nearly equal to corn per pound for poultry, when used in well-balanced rations. When grain sorghum replaces yellow corn in poultry feeding, care must be taken to furnish plenty of vitamin A value in the other feeds. Also, a large proportion of grain sorghum in a broiler ration will produce white skinned and shanked birds, unless enough alfalfa meal or corn gluten meal is included to give the desired yellow color.

Ground grain sorghum can be used in poultry mashes in the same manner as ground corn, and the whole grain can be fed as part of the scratch grain. There are apparently no marked differences in the values of the various grain sorghums for poultry, except that the varieties with white or yellow seeds seem to be more palatable to them. In most of the experiments in which milo, kafir, hegari, and kalo have been fed to chicks or laying hens as part of a well-balanced ration, these grain sorghums have been nearly equal to corn in value.[90]

780. Sorghum gluten meal; sorghum gluten feed.—Starch is produced from grain sorghum in a process similar to that used for corn starch. The by-products, *sorghum gluten meal* and *sorghum gluten feed* resemble corn gluten meal and corn gluten feed in composition, except that the sorghum feeds have somewhat more fat. They are not very palatable to stock and should therefore be mixed with well-liked feeds.

The Texas Station has conducted several experiments to find the value of these sorghum feeds for various kinds of stock.[91] Sorghum gluten meal was nearly equal to cottonseed meal as the protein supplement for dairy cows and equal to cottonseed meal for fattening cattle. For fattening lambs it equalled cottonseed meal with legume roughage, but was worth only 85 per cent as much with non-legume roughage. For pigs it was satisfactory as 30 per cent of the protein supplemental mixture, when combined with feeds that had protein of better quality. For poultry it could be used much like corn gluten meal.

Sorgum gluten feed may be used in rations for cattle or sheep in the same manner as corn gluten feed, except that, because of its low palatability, it had best not form more than about one-third of the concentrate mixture.

781. Sweet sorghum seed.—The seed of the sweet sorghums, or sorgos, contains considerable tannin, which makes it bitter and astringent. Its feeding value apparently differs considerably for the various kinds of stock.

While sweet sorghum seed has been said to have a tendency to dry up dairy cows, ground sweet sorghum seed gave as good results as ground corn in Kansas tests, when forming more than half of the concentrate mixture.[92] Ground sorghum heads also were satisfactory, when making up two-thirds of the concentrates.

In experiments with fattening cattle and lambs, however, ground sweet sorghum seed has often been decidedly inferior to grain sorghum and not worth more than two-thirds as much as corn.[93] Likewise, when fed to pigs in 6 tests, ground sweet sorghum seed has produced much less rapid gains than grain sorghum, and has been worth only about 68 per cent as much as corn.[94] Due to the small size of the seeds, sweet sorghum grain should be ground for all classes of stock except sheep.

782. Broom corn seed.—In harvesting broom corn, which is one of the sorghums, the heads are cut before the seed has fully matured, and the seed is removed from the brush before it is thoroughly dry. This seed has considerable feeding value and may be saved by drying or ensiling. In an Oklahoma test with fattening pigs, ground broom corn seed gave better results when forming one-fourth of the ration than when forming one-half.[95] Thus fed, it was worth 60 per cent as much as corn.

V. Rice and Its By-products

783. Rice; rough rice; chicken-feed rice.—Rice (*Oryza sativa*) is one of the most important cereal crops of the world and forms a large part of the food of Oriental peoples. In this country rice production is important only in Louisiana, Texas, Arkansas, and California. Rice is used almost entirely for human food and is fed to stock only when off-grade or unusually low in price.

The rice kernels are very hard and are enclosed in hard hulls, which have sharp ridges with tooth-like projections. The threshed grain, called rough rice, or paddy rice, is nearly as high as oats in fiber and is even lower than corn in protein. Rough rice may be used as a substitute for other grain in stock feeding. It has the common merits of the cereals as a feed and also the same general deficiencies, including a lack of carotene. Because of the hardness of the kernels, it should always be ground, except perhaps for poultry. The grinding should be fine enough to reduce the hulls to a meal.

For dairy cows and work horses or mules, ground rice has been about equal to ground corn.[96] In 4 experiments with fattening cattle, it produced somewhat less rapid gains than corn and was worth only about 81 per cent as much.[97] Similarly, in 4 experiments with fattening pigs, ground rough rice was worth about 84 per cent as much as corn.[98] It produces firm pork of good quality.

The value for fattening lambs has been lower than for other stock, ranging from 55 to 76 per cent of that of corn, when fed as the only grain.[99]

For laying hens, in rations containing adequate vitamin A from other sources, whole rough rice was satisfactory as 75 per cent of the scratch grain, and in an all-mash ration ground rough rice was a good substitute for ground corn as 35 per cent of the mash.[100]

784. Rice bran.—Rice bran consists of the rice bran and germs removed in milling rice for human food, and it should contain only such quantities of hull fragments as are unavoidable in the regular milling process. Rice bran of good quality averages 12.4 per cent in protein and 13.6 per cent in fat, with 11.6 per cent fiber. It is similar to oats and wheat in protein content, and decidedly lower than wheat bran or middlings. Rice bran supplies protein of considerably better quality than corn. It is rich in thiamine and very high in niacin.

Rice bran is fairly palatable when fresh, but it often turns rancid in storage, because of the high oil content. Thorough heating and drying at the mill improve the keeping quality. Recently, some solvent-extracted rice bran, low in fat, has been produced, which keeps well. Rice bran varies considerably in fiber content, depending on the proportion of hulls present, and sometimes it is adulterated with hulls. In purchasing rice bran, it is safest to buy it only on strict guarantee of composition, and also from a sample that has been examined for rancidity.

Rice bran is fed chiefly to dairy cattle. When forming not more than one-third the

concentrate mixture for dairy cows, it has been approximately equal to wheat bran and worth about 75 to 80 per cent as much as ground corn or milo grain.[101] Too large a proportion of rice bran causes soft butter.

Rice bran may also be used in place of part of the grain for beef cattle or sheep. Its value is two-thirds to three-fourths that of corn, when used as one-third the concentrates.[102]

Rice bran has given good results in swine feeding when forming not more than 25 to 30 per cent of the ration.[103] When thus fed, it has been usually worth fully as much as corn, and sometimes even more. Used in place of wheat standard middlings or wheat shorts, it is worth nearly as much per pound as these feeds.

When rice bran forms a larger part of the ration, it tends to produce soft pork, unless it is solvent-extracted rice bran. When rice bran makes up more than about 30 per cent of the ration for pigs, the rice bran is worth only about 86 per cent as much as corn. Too large a proportion of rice bran is also apt to cause serious scouring of pigs under 75 lbs. in weight.

Rice bran can be used in place of wheat bran or wheat middlings in poultry feeding, if the ration does not include rough rice as well.[104]

785. Rice polishings, or rice polish.—Rice polishings, also called "rice polish," are the finely powdered material obtained in polishing the rice kernels, after the hulls and bran have been removed. They contain as much protein and nearly as much fat as rice bran, have only 2.7 per cent fiber, and supply fully as much total digestible nutrients as corn. Rice polishings are rich in thiamine and especially high in niacin. Though not rich in riboflavin, the content is somewhat higher than in the whole cereal grains. They tend to become rancid in storage, like rice bran, and should therefore be fed when as fresh as possible.

Rice polishings are satisfactory as part of the concentrate mixture for dairy cattle, beef cattle, and sheep. In Arkansas trials they were equal to ground corn for dairy cows when forming one-fourth of the concentrate mixture, but when as much as this was fed soft butter was produced.[105] For fattening cattle rice polishings were worth only 88 per cent as much as corn in 3 Louisiana tests.[106]

Rice polishings have the highest value in swine feeding. Though they have some of the same limitations as rice bran as a swine feed, they have been worth 121 per cent as much as corn when used to replace one-third of the corn for pigs, and 112 per cent as much as corn when forming a larger part of the ration.[107]

Rice polishings tend to produce soft pork, especially when forming more than one-half of the ration for fattening pigs. They are also apt to cause serious scours if too much is fed to pigs under about 75 to 80 lbs. in weight. Rice polishings are entirely satisfactory as part of the ration for brood sows and litters. If the pigs are then grown and finished on non-softening feeds, their carcasses will not be soft.

786. Brewers' rice; rice meal.—*Brewers' rice* consists of the small pieces of broken kernels that are removed from the whole kernels in the milling process. It is used chiefly in the brewing industry, but is sometimes fed to stock. Brewers' rice furnishes about as much total digestible nutrients per 100 lbs. as the grain sorghums or barley. As it may be less palatable than grain, it is best to mix it with well-liked feeds. In 22 experiments with fattening pigs, brewers' rice has been worth about 6 per cent more than corn,[108] but in one test with fattening cattle, it was not quite equal to corn.[109] Brewers' rice produces hard pork of good quality.

Rice meal, according to the definition of the Association of American Feed Control Officials, should be ground brown rice (ground rice after the hull has been removed).[18] The term is, however, used sometimes for entire ground rice, including the hulls. Rice meal is nearly equal to corn for stock feeding.[110]

787. Rice hulls; rice mill by-product.—*Rice hulls* have a very low value as a feed, for they furnish only about one-fourth as much total digestible nutrients as does oat straw, and practically no digestible protein. When there is a serious shortage of roughage, well ground rice hulls may be substituted for a small part of the roughage usually fed cattle, in order to carry them through the period of deficient feed supply.

In Arkansas trials in which ground rice hulls, mixed with the concentrate allowance, replaced 15 to 25 per cent of the prairie hay in a ration for wintering beef steers, fair gains were made, but less than on rations without the hulls.[111] The rice hulls, thus fed, had a very low value per ton in comparison with prairie hay. Unsatisfactory results were secured in Texas experiments with beef steers when rice hulls were used as the only roughage, in place of cottonseed hulls.[112]

It has sometimes been stated that the sharp edges of rice hulls may irritate the

digestive tracts of stock. However, in a Louisiana test no such effect was produced by feeding growing steers a mixture containing as much as 30 per cent ground rice hulls.[113]

Rice mill by-product is the name proposed by the Association of American Feed Control Officials for the entire by-product obtained in the milling of rice, including the hulls, rice bran, rice polish, and broken grains.[18] This is sometimes called "rice mill feed." The fiber content should not exceed 30 per cent. About 60 per cent of such a product would be rice hulls. In an Arkansas trial steers being carried through the winter gained decidedly less on rice mill feed as the only roughage, plus 3 lbs. of concentrates a day, than on prairie hay with the same concentrate allowance.[111] In another Arkansas trial rice mill feed was a satisfactory substitute for two-thirds the prairie hay in a properly supplemented ration for wintering steer calves.

VI. Emmer; Spelt; Millet

788. Emmer and spelt.—Emmer (*Triticum dicoccum*) and spelt (*Triticum spelta*) are close relatives of wheat, but the grain resembles barley in appearance, for the hulls are not usually removed from the kernels in threshing. These grains have never become of any importance in the United States, because the other cereals are more productive in most sections. Three-fourths of the acreage (mostly emmer) is in North and South Dakota.

Emmer is often incorrectly called "speltz" or "spelt." Spelt is grown but little in this country and has been largely displaced by other grains where it was once raised in Europe.

Emmer and spelt closely resemble oats in composition. They may be used in the same manner as oats in feeding the various classes of stock and have about the same value as oats per 100 lbs.[114] The weight of these grains per bushel varies considerably, a common weight being 40 lbs. per bushel.

When a large proportion of the hulls is removed in threshing, emmer will resemble barley more than oats in composition and feeding value.

789. Millet.—The only kind of millet grown in this country as a grain crop is hog millet (*Panicum milaceum*), or proso, also called broom-corn millet. It is the ordinary millet of the Old World, which has been raised since prehistoric times as an important grain crop for human food. The forage types of millet have been discussed in Chapter XVIII.

Hog millet has spreading or panicled heads, wide, hairy leaves, and large seeds. It is not raised for grain to any extent in this country except in the most northern part of the great plains, where the growing season is too short for the grain sorghums. Here it is often grown as a late-sown catch crop, for other cereals will usually outyield it if seeded at the normal time. The yields usually range from 10 to 30 bushels per acre.

Hog millet gives satisfactory results when used as a substitute for other grain. It should always be ground for all classes of stock except poultry. In experiments ground hog millet has been worth from 75 to 90 per cent as much as corn for fattening cattle and lambs; from fully equal to corn to 85 per cent of the value of corn for pigs; and 95 per cent as much as corn for laying hens.[115]

Finely ground foxtail millet seed was fully equal to shelled corn for growing and fattening pigs in a Kansas trial.[116]

VII. Buckwheat and Its By-products

790. Buckwheat.—Buckwheat (*Fagopyrum esculentum*) is not really a cereal but belongs to an entirely different family of plants. It is discussed here because the seed has much the same general nutritive characteristics as the cereal grains. Buckwheat often does better than the small grains on poor or very acid soil, and it is also frequently grown as a late-sown catch crop, because of its short growing season. Buckwheat is raised chiefly for the manufacture of buckwheat flour and other human foods, but it is sometimes fed to stock when the grain is low in price.

The woody hulls of buckwheat form 18 to 20 per cent or more of the seed, and the grain has 10.7 per cent fiber, which is about as much as oats. It has somewhat less protein than oats and only about one-half as much fat, and it furnishes appreciably less total digestible nutrients. It is not so palatable as most of the grains. It should therefore be mixed with well-liked feeds and should preferably not form more than one-third of the mixture.

It is of interest that in recent Arkansas studies with rats it was found that the protein of whole buckwheat or buckwheat flour was of much higher nutritive value than that in other plant products, even soybean oil meal.[117]

Buckwheat should be ground for all classes of stock except poultry. Fed in a

suitable mixture, ground buckwheat is probably worth 5 to 10 per cent less than ground oats for dairy cows or other cattle. In 3 Tennessee trials pigs on pasture gained slightly more rapidly on shelled corn and protein supplement than when ground buckwheat replaced all or one-half of the corn.[118] In these trials ground buckwheat was worth 71 per cent as much per pound as corn. In Canadian trials it was somewhat inferior to wheat or wheat middlings for fattening pigs.[119] Occasionally, buckwheat grain and also the green fodder or straw cause peculiar eruptions and intense itching of the skin. This affects only white or light-colored portions of the hide, and animals are usually thus injured only when exposed to light.

Tartary buckwheat (*Fagopyrum tataricum*), also called "India wheat" or "rye buckwheat," is higher in hull and lower in milling quality and in feeding value than ordinary buckwheat. However, it does better on very poor soil, is more frost-resistant, and yields better under adverse conditions.

791. Buckwheat by-products.—*Buckwheat middlings* are the portions of the buckwheat grain immediately inside the hull, which are separated from the flour in the milling process. They contain 29.7 per cent protein and only 7.4 per cent fiber, and they are about equal to gluten feed or brewers' dried grains in value.[120] They are generally used for dairy cows and are a satisfactory protein supplement when forming not over one-third the concentrate mixture. They may also be used as a substitute for wheat middlings in feeding swine and other stock. They are not satisfactory as the only protein supplement for pigs, but should be combined with supplements like meat scrap or tankage, which provide better protein.[121]

Sometimes buckwheat hulls (which have very little feeding value) are mixed with buckwheat middlings to form *buckwheat feed*. The value of this will depend on the proportion of hulls. If buckwheat feed has 20 per cent fiber, it will be about one-third hulls.

Buckwheat hulls are woody, high in fiber, and exceedingly low in digestibility. Since they supply only one-third as much total digestible nutrients as wheat straw, they have very little feeding value. They should be used for fuel, bedding, or packing, rather than for feed.

QUESTIONS

1. Compare the composition of wheat and corn.
2. Discuss the value and use of wheat for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry.
3. Describe the manufacture of flour from wheat, and state the by-products secured in the milling process.
4. Discuss the composition of: (a) Wheat bran; (b) standard wheat middlings, or brown shorts; (c) wheat red dog, or white shorts; (d) wheat flour middlings, or gray shorts; (e) wheat mixed feed; (f) wheat germ meal.
5. What wheat by-products are chiefly used for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry?
6. Compare the composition of barley and corn.
7. What is the value of barley, compared with corn for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry?
8. Describe the malting process and state the by-products that are produced for feeding.
9. Discuss the composition and use of brewers' dried grains; of malt sprouts.
10. What limitations has rye as a feed for livestock?
11. What is the chief rye by-product? Compare its composition with that of standard wheat middlings.
12. Discuss the composition and feeding value of the grain sorghums, in comparison with corn.
13. If any of the following are of importance in your district, summarize briefly the information concerning their composition and feeding value: (a) Rough rice; (b) rice bran; (c) rice polish; (d) rice hulls; (e) emmer; (f) hog millet; (g) buckwheat; (h) buckwheat middlings.

REFERENCES

1. Fitch and Cave, Kan. Rpt. 1930–32; Ky. Rpt. 1931; Bartlett, Me. Rpt. 1895; Dice, N.D. Bul. 256; Hayden and Monroe, Ohio Buls. 497, 516, 532; Ohio Spec. Cir. 70; Jacobs, Okla. Panhandle Sta. Bul. 29; Ore. Bul. 401; Copeland, Tex. Bul. 480; Bateman, Utah Farm and Home Sci., 3, 1942, No. 4.
2. Ga. Rpts. 1946, 1947, 1948, 1949; Dyer and Weaver, Mo. Bul. 641.
3. Morton and Osland, Colo. Press Bul. 78; Rusk and Snapp, Ill. Rpt. 1931; Skinner and King, Ind. Bul. 396; Weber and Connell, Kan. Bul. 261; Md. Rpts. 1943, 1944; Peters, Minn. Bul. 300; Dickson, Mont. Bul. 359; Thalman and Gramlich, Nebr. Bul. 355; Baker, Nebr. Bul. 295; Christensen, N.D. Bul. 256.
4. Weber and Connell, Kan. Bul. 261; Branaman, Mich. Quar. Bul., 27, 1941, No. 1; Blizzard, Okla. Cattleman, 11, 1925, pp.

49–51; Taylor and Blizzard, Okla., mimeo. rpt.; Darlow et al., Okla. Bul. 296 and mimeo. rpts.; Potter, Withycombe, and Edwards, Ore. Bul. 276; Singleton, Ensminger, and Heineman, Wash. Bul. 469; see also: Good and Harris, Ky. Bul. 332, Trowbridge and Moffett, Mo. Bul. 325; Baker, Nebr. Buls. 263, 295; Hostetler and Foster, N.C. Rpt. 1932.

5. Morton and Osland, Colo. Press Bul. 78; Peters, Minn. Bul. 300; Vinke and Pearson, Mont. Bul. 251; see also: Stanley, Ariz. Bul. 198.
6. Stanley, Ariz. Bul. 198; Darlow, Campbell, Cross, Heller, and Briggs, Okla. Bul. 296 and mimeo. rpt.; Ore. Bul. 359; Ore. Cir. 137.
7. Rinehart, Hickman, and Johnson, Id. Bul. 194; Saunderson and Vinke, Mont. Bul. 249; Holden, Scottsbluff, Nebr. Substa., mimeo. rpt.; Mackey and Jones, Tex. Bul. 465.
8. Morton and Fairbanks, Colo. Press Bul. 79; Johnson, Rinehart, and Hickman, Id. Bul. 194; Jordan and Peters, Minn. Bul. 306; Potter and Dean, Ore. Bul. 198; Richards, Ore. Bul. 370; Maynard, Esplin, and Boswell, Utah Bul. 328; Hackedorn, Sotola, and Singleton, Wash. Bul. 258.
9. Morton and Fairbanks, Colo. Press Bul. 79; Johnson, Rinehart, and Hickman, Id. Bul. 194; Kammlade, Ill., mimeo. rpt.; Mumford, Mich. Bul. 128; Brown, Mich. Spec. Bul. 233; Baker, Nebr. Bul. 256 and information to the author; Weber and Loeffel, Nebr. Bul. 257; Darlow, Okla. Bul. 213; Potter and Dean, Ore. Bul. 198; Maynard, Esplin, and Boswell, Utah Bul. 238; Hackedorn, Sotola, and Singleton, Wash. Bul. 258.
10. Kammlade, Ill. Rpt. 1931; Darlow, Okla. Bul. 213; Weber and Loeffel, Nebr. Bul. 257; Hackedorn, Sotola, and Singleton, Wash. Buls. 258, 275.
11. Vestal, Ind., mimeo. rpts.; Aubel and Connell, Kan. Cir. 188; Carmichael, Md. Bul. 336; Freeman, Mich. Quar. Buls., 13, 1931, No. 3; 18, 1935, No. 2; Peters and Ferrin, Minn., mimeo. rpt.; Weaver, Mo. Bul. 328; Loeffel, Nebr. Bul. 261 and mimeo. rpt.; Loeffel and Lewis, Nebr., mimeo. rpt.; Wilson and Wright, S.D., mimeo. rpt.; Quayle, Wyo. Bul. 256; see also: Tomhave, Del. Bul. 172; Culbertson, Iowa Rpt. 1943, Part 2; Ky. Rpt. 1930; Weaver, Mo. Bul. 136; N.C. Rpt. 1943; Eastwood, Ohio Bul. 268.
12. Peters, Ferrin, and Johnson, Minn., mimeo. rpt.; Minn., Crookston, Substa., Rpt. 1924; Vinke and Bergstedt, Mont. Bul. 284; Mont. Rpt. 1931; Longwell and Huber, N.D. Bimo. Bul., 8, 1945, No. 1; Headley, Nev. Bul. 166; Smith and Young, Utah Bul. 254; Quayle, Wyo. Bul. 256.
13. Aubel and Connell, Kan., Cir. 188; Freeman, Mich. Quar. Bul., 18, 1935, No. 2; Loeffel and Lewis, Nebr., mimeo. rpt.; Thompson, Okla. Rpts. 1930–32, 1934–36; Hale, Tex. Rpts. 1932, 1933; see also: Bliss and Lee, Nebr. Bul. 144; Snyder, Nebr. Bul. 147; Loeffel, Nebr., mimeo. rpt.; Willman and Morrison, N.Y. (Cornell) Bul. 836; Withycombe, Ore. Bul. 80.
14. Thompson, Okla. Bul. 165 and Okla. Rpts. 1930–32, 1934–36.
15. Culbertson, Iowa Rpt. 1943, Part 2; Quayle, Wyo. Bul. 256.
16. Roberts and Carrick, Ind. Rpt. 1938; Heuser, N.Y., Poultry Sci., 22, 1943, pp. 123–125; Kennard and Chamberlin, Ohio Bimo. Buls. 220, 221; Wilson, S.D. Bul. 376; Carver, Wash. Bul. 394; Whitson, Hammond, Titus, and Bird, U.S.D.A., Poultry Sci., 24, 1945, pp. 408–416.
17. Kennard and Chamberlin, Ohio Bimo. Bul. 230.
18. Assoc. Amer. Feed Control Officials, Official Pub., 1956.
19. Kusmeski, Mass., information to the author.
20. Skinner and Starr, Ind. Bul. 219; Robison, Ohio Bul. 607; Grimes, Penn. Buls. 196, 215, 230.
21. Smith, Nebr. Buls. 100, 132; Tomhave and Gerlaugh, Penn. Buls. 133, 145.
22. McCampbell and Aicher, Kan., Annual Cattlemens' Roundup, 1938, 1939, 1940, 1942.
23. Iddings, Id. Bul. 89; Griswold, N.D. Bul. 217.
24. Keith, Penn. Bul. 429
25. Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834.
26. Rice and Laible, Ill., mimeo. rpt.; Waters et al., Kan. Bul. 192; Ferrin and Winchester, Kan. Cir. 78; Weaver, Mo. Bul. 144; Loeffel, Nebr., mimeo. rpt.; Robison, Ohio Bul. 355; Grimes, Penn. Bul. 215.
27. Aubel and Alexander, Kan. Cir. 187; Gramlich and Jenkins, Nebr. Bul. 175.
28. Martin, Ark., mimeo. rpt.; Rice, Ill. Bul. 247; Ferrin and McCarty, Minn. Bul. 219; Loeffel, Nebr., mimeo. rpt.
29. Gramlich and Jenkins, Nebr. Bul. 175; Robison, Ohio Bul. 349.
30. Evvard, Iowa, mimeo. rpt.; Loeffel, Nebr., mimeo. rpt.; Morrison and Bohstedt, Wis. Bul. 323.
31. Ferrin and McCarty, Minn. Bul. 219; Robison, Ohio Buls. 488, 607; Starkey and Salmon, S.C. Bul. 213.
32. Taylor and Lerner, Cal., Poultry Sci., 18, 1939, pp. 323–326; Ind. Rpt. 1936; Mussehl, Ackerson, and Blish, Nebr. Res. Bul. 119.
33. Sherwood and Couch, Tex. Bul. 525; Tex. Rpt. 1944; Clark and VanLandingham, West Va. Rpt. 1936–38.
34. Cunningham, Ariz. Bul. 127; Burnett and Reed, Mich. Quar. Bul., 10, 1927, No. 1: Dice, N.D. Bul. 286; Morrison, Humphrey, and Hulce, Wis. Bul. 319.
35. Darnell and Copeland, Tex. Bul. 530; Bohstedt, Roche, Fargo, Rupel, and Duffee, Wis. Bul. 421.
36. Morton, Colo. Rpt. 1927; Hickman, Rinehart, and Johnson, Id. Bul. 209; Rusk and Snapp, Ill., mimeo. rpt.; Haney, Kan. Bul. 128; Weber and Connell, Kan. Rpt. 1934–36; Leinbach, Md. Bul. A-20; Branaman, Mich. Spec. Bul. 280; Peters and Carnes, Minn. Bul. 200; Peters, Minn. Buls. 274, 300; Trowbridge, Dyer, and Comfort, Mo. Bul. 641; Miss. Rpt. 1941; Baker, Nebr. Bul. 350; Foster and Simpson, New Mex. Bul. 101; Hostetler and Foster, N.C. Rpt. 1932; Blizzard, Okla. Bul. 147; Blizzard and Taylor, Okla. Rpt. 1938–40; Potter, Withycombe, and Edwards, Ore. Bul. 276; Hoffman, Bogart, and Burris, Ore. Bul. 528; Wilson, S.D. Bul. 160; Texas Rpt. 1950; Fuller, Morrison, and Fargo, Wis. Bul. 323.
37. Baker, Nebr. Bul. 350; Tippit, Jones, and Johnston, Texas Progress Rpt. 1333.
38. Stanley, Ariz. Bul. 198; see also: Johnson, Keith, and Lehrer, Id. Bul. 225.
39. Christensen, N.D. Bul. 264.
40. Vinke and Pearson, Mont. Bul. 251.
41. Buffum and Griffith, Colo. Bul. 75; Morton, Colo. Bul. 187; Maynard, Morton, and Osland, Colo. Bul. 379; Morton, Maynard, and

Fairbanks, Colo. Press Bul. 76; Morton and Fairbanks, Colo. Press Bul. 79; Colo. Rpt. 1939; Hickman, Rinehart, and Johnson, Id. Buls. 194, 270; Kammlade, Ill. Bul. 338; Evvard, Dunn, and Culbertson, Iowa Bul. 210; Paterson and Winchester, Kan. Cir. 88; Brown, Mich. Spec. Bul. 233; Jordan and Peters, Minn. Bul. 306; Fox, Nebr. Bul. 211; Holden Nebr. Buls. 216, 268; Darlow, Okla. Buls. 146, 196; Briggs, Okla. Bul. B-272; Potter and Dean, Ore. Bul. 198; Wilson and Fenn, S.D. Bul. 359; Johnson and Johnson, S.D. Bul. 273; Maynard, Esplin, and Boswell, Utah Bul. 238; Hackedorn, Singleton, and Sotola, Wash. Bul. 351; Hackedorn, Singleton and Burkitt, Wash. Bul. 394; Faville, Wyo. Buls. 81, 103; Quayle, Wyo. Bul. 191.

42. Harper, N.Y. (Cornell) Rpt. 1931; Shepperd, N.D. Bul. 45; Morrison, Fuller, and Bohstedt, Wis. Bul. 319; Lavalard, Expt. Sta. Rec., 12, 1900, p. 14.

43. Aubel, Kan. Cir. 258; Brown, Mich. Rpt. 1922; Freeman, Mich. Quar. Bul., 18, 1935, No. 2; Carnes, Minn., Duroc Digest, Nov. 1, 1921; Ferrin and McCarty, Minn., mimeo. rpt.; Dinusson, Light, Bolin, and Buchanan, N.D. Bimo. Bul., 15, 1953, No. 4; Wilson and Kuhlman, S.D. Bul. 192; Wilson and Wright, S.D. Buls. 262, 316; Wright, S.D. Rpt. 1944 and Amer. Soc. Anim. Prod., Proc. 1938; Wilson, S.D. Farm and Home Res., 4, 1953, No. 2; Morrison and Bohstedt, Wis. Bul. 319; see also: Maynard and Brandon, Colo. Press Bul. 69; Id. Bul. 131; Bull, Carroll, et al., Ill. Bul. 366; Vestal, Ind., mimeo. rpt.; Peters, Ferrin, and Johnson, Minn., mimeo. rpt.; Weaver, Mo. Bul. 172; Hansen, Mont. Rpt. 1921; Joseph, Mont. Bul. 169; Quesenberry et al., Mont., Rpt. 1927; Weaver, Mo. Bul. 477; Loeffel, Nebr. Bul. 251; Hanson, Nebr. Rpts. 1942, 1943; Robison, Ohio Bul. 607; Thompson, Okla. Bul. 198; McCarty, Penn. Buls. 266, 279; Duncan, Tenn. Rpt. 1945; Carroll, Utah Bul. 192; Willard, Wyo. Rpt. 1931; Quayle, Wyo. Bul. 256.

44. Ferrin and Winchester, Kan. Cir. 89; Edwards, Mich. Spec. Bul. 199; Loeffel, Nebr. Rpt. 1936; Christensen et al., N.D. Bul. 318; Wilson and Wright, S.D. Bul. 262; Morrison and Bohstedt, Wis., mimeo. rpt.; see also: Evvard, Iowa, mimeo. rpt.; Freeman, Mich. Quar. Bul., 15, 1933, No. 4; Miller, Minn., Morris Substa., Rpt. 1923; N.J. Rpt. 1941; Jacob, Tenn. Rpts. 1938, 1940.

45. Crampton, Muir, and Knox, Sci. Agri., Canada, 20, 1940, pp. 365–401.

46. Freeman, Mich. Quar. Bul., 18, 1935, No. 2; Arnett, Mont. Rpts., 1922, 1923; Joseph, Mont. Rpt. 1924; Nebr. Rpt. 1934; Dinusson, Light, Bolin, and Buchanan, N.D. Bimo. Bul., 15, 1953, No. 4; Thompson, Okla. Bul. 198; Thompson and Hillier, Okla. Rpts. 1938–40, 1940–42; Oliver, Ore. Cir. 104; Wilson and Kuhlman, S.D. Bul. 192; Wilson and Wright, S.D. Bul. 252; Hale, Tex. Rpts. 1931, 1932, 1933; Bohstedt, Roche, Fargo, Rupel, and Duffee, Wis. Bul. 421, and Amer. Soc. Anim. Prod., Proc. 1931; see also: Hanson, Nebr. Rpts. 1942, 1943; Ore. Rpt. 1924–1926; Wyo. Rpt. 1929; Sinclair, Univ. of Alberta, Canada, mimeo. rpt.

47. Good, Ky. Rpt. 1923; Loeffel, Nebr. Bul. 251; Arnett, Mont. Rpts. 1922, 1923; Joseph, Mont. Rpt. 1924; Ore. Rpt. 1924–1926; Thompson, Okla. Bul. 198; Wilson and Kuhlman, S.D. Bul. 192; Morrison and Bohstedt, Wis. Bul. 319.

48. Hanson and Ferrin, Minn., mimeo. rpt.; Wright, S.D. Bul. 366; Wilson and Barnett, S.D. Rpt. 63.

49. Ferrin and Peters, Minn., mimeo. rpt.; Severson, N.D. Bul. 264.

50. Joseph, Mont. Bul. 169.

51. Peterson and Zweigart, Cal. Agr., 8, 1954, No. 3; see also Peterson and Lampman, Id. Bul. 238.

52. Hinds, Ariz. Bul. 184.

53. Fraps, Texas Bul. 678.

54. Lindblad, Aitken, and Hunsaker, Canada, Poultry Sci., 33, 1954, p. 1067; Arscott Johnson, and Parker, Ore., Poultry Sci., 34, 1955, pp. 655–661; see also: Kempster, Mo. Bul. 438.

55. Lindsey, Mass. Bul. 94; Hills, Vt. Rpt. 1903.

56. Borland, Penn. Bul. 446.

57 Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834.

58. Rusk and Snapp, Ill. Rpt. 1937.

59. Halnan, Minister of Agr. Jour., Great Britain, 30, 1924, p. 960; Voorhees, N.J. Rpt. 1892.

60. Tomhave, Del. Bul. 205; Willman, N.Y., information to the author.

61. Crampton and Lloyd, Macdonald College, Canada, Jour. Anim. Sci., 13, 1954, pp. 638–647; Crampton, MacKay, and Lloyd, Jour. Anim. Sci., 14, 1955, pp. 688–692.

62. Davies and Sullivan, Jour. Agr. Sci., England, 17, 1927, pp. 380–387; Mangold, Handb. Ernähr. und Stoffwechsels, Vol. I.

63. Morrison, Humphrey, and Hulce, Wis. Bul. 302.

64. Lawes and Gilbert, Rothamsted Memoirs, Vol. IV.

65. Tretsven, Mont. Bul. 303; Hayward, Penn. Bul. 52.

66. Tretsven, Mont. Bul. 282; see also: Hirst and Eckles, Minn., information to the author.

67. Baker, Nebr. Bul. 350; Wilson and Wright, S.D. Bul. 271; see also: Peters, Minn. Bul. 330; Kiser, Christgau, and Peters, Minn., mimeo. rpt.; Vinke, Morgan, and Sandberg, Mont., mimeo. rpt.; Ore. Bul. 401; Ore. Cir. 137.

68. Jordan and Peters, Minn. Bul. 306; Baker, Nebr. Bul. 256 and information to the author.

69. Colo. Rpt. 1938; Vestal, Ind., mimeo. rpt.; Brown, Mich. Rpt. 1922; Ferrin, Minn., Amer. Soc. Anim. Prod., Proc. 1925–1926; Peters, Ferrin, and Johnson, Minn., mimeo, rpt.; Morgan and Arnett, Mont. Bul. 192; Vinke and Bergstedt, Mont. Bul. 284; Nebr. Rpts. 1932, 1934; Ore. Rpt. 1924–1926; McCarty, Penn. Buls. 279, 293; Wilson and Wright, S.D. Bul. 271; Willard, Wyo. Rpt. 1931; Wheeler, Wyo. Bul. 265.

70. Nebr. Rpt. 1936; Ackerson, Ham, and Mussehl, Nebr. Res. Bul. 146; Halpin, Holmes, and Hart, Wis., Poultry Sci., 15, 1936, pp. 3–8; Wyo. Rpts. 1936, 1939, 1940.

71. Cunningham, Ariz. Bul. 127; Cave and Fitch, Kan. Cir. 119; Fitch, Cave, Riddell, and Merrill, Kan. Rpt. 1932–34; Moore, Miss. Rpts. 1928, 1929; Nebr. Rpt. 1940; Olson, S.D. Rpt. 1943.

72. Fitch and Wolberg, Jour. Dairy Sci., 17, 1934, pp. 343–350; Atkeson and Beck, Jour. Dairy Sci., 25, 1942, pp. 211–220.

73. Haney, Kan. Bul. 132; Cochel, Kan., mimeo. rpt.; Weber and Aicher, Kan. Round-up. Cirs. 32, 33; Aicher, Kessler, and Weber,

Kan. Cir. 271; Richardson, Smith, Cox, and Keating, Kan. Cir. 308; Thalman, Nebr. Bul. 347; Baker, Nebr. Bul. 350; Foster and Simpson, New Mex. Bul. 101; Blizzard, Okla. Buls. 147, 237; Pope, Humphrey, Heller, and Campbell, Okla. Misc. Pub. MP-31; S.D. Rpt. 1942; Burns, Tex. Bul. 110; Marion, Fisher, and Jones, Tex. Progress Rpt. 1599.

74. Smith, Parrish, Cox, and Pickett, Kan. Cirs. 250, 283, 297; Baker, Smith, Cox, and Richardson, Kan. Cir. 320.
75. Jones, Jones, Black, and Keating, Tex. Bul. 547; Black, Jones, and Keating, U.S.D.A. Tech. Bul. 581.
76. Kidder, Fla. Bul. 391; Black, Ellis, Jones, and Keating, U.S.D.A., Tech. Bul. 945.
77. Tex. Bul. 724.
78. Colo. Rpt. 1939; Paterson and Marston, Kan. Cir. 109; Reed and Marston, Kan. Cir. 123; Cox and Connell, Kan. Rpt. 1932–34; Cox, Kan. Rpt. 1938; Nebr. Rpts. 1939, 1940; Darlow, Okla. Buls. 146, 196.
79. Cochel, Kan., information to the author; Paterson and Marston, Kan. Cir. 109; Nebr. Rpt. 1938; Darlow, Okla. Buls. 146, 196; Jones and Dickson, Tex. Bul. 379; Mackey and Jones, Tex. Bul. 465.
80. Bell and Erhart, Kan. Cirs. 283, 297, 308; Willey, Jones, and Lyerly, Tex. Bul. 733.
81. Paterson and Marston, Kan. Cir. 109; Cox and Sloan, Kan. Rpt. 1936–38; Darlow and Craft, Okla. Bul. 196; Jones and Dickson, Tex. Bul. 379; Jones, McDowell, and Jones, Tex. Rpt. 1933; Jones, Brooks, and Jones, Tex. Rpt. 1941.
82. Cox, Kan. Rpt. 1936–38.
83. Wilson and Burkitt, S.D. Rpts. 1942, 1943, 1944.
84. Dvorachek and Sandhouse, Ark. Cir. 34; Cochel, Kan. Industrialist, May 1, 1915; Waters et al., Kan. Bul. 192; Ferrin and Winchester, Kan. Cir. 89; Aubel and Alexander, Kan. Cir. 187; Aubel, Kan. Bul. 344, Circs. 258, 287, 308; Fletcher, Miss. Bul. 504; Weaver, Mo. Bul. 444; Nebr. Rpts. 1936, 1938, 1939; Malone, Okla. Bul. 120; Hillier, MacVicar, and Pond, Okla. Misc. Pub. MP-34; Wright, S.D. Rpts. 1940, 1942; Wilson, S.D. Farm and Home Res., 5, 1954, No. 2; Warren, Tex. Bul. 305; Hale, Tex., mimeo. rpt.
85. Hillier, MacVicar, and Ewing, Okla. Misc. Pub. MP-43.
86. Williams and Stanley, Ariz. Rpt. 1922; Williams, Burns, and Smith, Ariz. Rpt. 1923; Thompson, Okla. Bul. 144.
87. Thompson, Okla. Bul. 165, Okla. Rpt. 1926–1930; see also: Thompson and Voorhies, Cal. Bul. 342.
88. Cochel, Kansas Industrialist, May 1, 1915; Aubel, Kan. Cir. 308; Loeffel, Nebr. Rpt. 1938 and mimeo. rpt.; Baker and Reinmiller, Nebr. Bul. 323; N. Mex. Rpt. 1942; Thompson, Okla. Bul. 165 and Okla. Rpt. 1934–36; Wright, S.D. Rpts. 1942, 1944; Wilson, S.D. Farm and Home. Res., 5, 1954, No. 2; Hale, Tex. Rpts. 1929, 1930, 1932.
89. Smith and Grimes, Ala. Rpt. 1947–48; Hughes and Heitman, Cal. Bul. 709; Loeffel, Nebr. Rpts. 1938, 1940.
90. Hinds, Ariz. Bul. 184; Miss. Rpt. 66; Kempster, Mo. Bul. 457; Ackerson, Blish, and Mussehl, Nebr. Res. Bul. 109; Nebr. Rpt. 1941; Berry, New Mex. Bul. 392; Boone, Morgan, and Cooper, S.C. Rpt. 61; Hall, Carter, and Sherwood, Tex. Rpt. 1943; Hammond, Poultry Sci., 21, 1942, pp. 410–415.
91. Shelton et al., Tex. Bul. 743; Tex. Bul. 724.
92. Cave and Fitch, Kan. Cir. 110; Fitch and Cave, Kan. Rpts. 1928–30; 1930–32; Fitch, Cave, Riddell, and Merrill, Kan. Rpt. 1932–34.
93. McCampbell, Winchester, and Marston, Kan. Cir. 97; Johnson and Fenn, S.D. Rpts. 1940, 1942; Jordan, Burkitt, and Wilson, S.D. Bul. 417; see also: Cox and Wagner, Kan., Amer. Soc. Anim. Prod., Proc. 1937.
94. Waters et al., Kan. Bul. 192; Bell, Winchester, and Marston, Kan. Cir. 128; Snyder, Nebr. Bul. 124; Okla. Rpt. 1921.
95. Thompson, Okla. Rpt. 1940–42 and mimeo. rpt.
96. Dvorachek, Ark. Bul. 203; Dalrymple, La. Bul. 122; Calloway, La. Rpt. 1921.
97. Snell, Bray, Morrison, and Jackson, La. Bul. 389; Weaver and Moffett, Mo. Bul. 386.
98. Bray, La. Bul. 368; Dyer and Weaver, Mo. Bul. 641; see also: Martin, Ark. Bul. 323; Hughes, Cal. Bul. 420; Hale, Tex. Rpt. 1931.
99. Snell and Morrison, La., Rice Jour., 43, 1940, pp. 13–14; Weaver and Moffett, Mo. Bul. 386.
100. Smith, Ark. Bul. 478.
101. Dvorachek, Ark. Bul. 215; Lush and Hale, Tex. Bul. 352.
102. Miller, Cal., mimeo. rpts.; Snell, Bray, Morrison, and Jackson, La. Bul. 389; Craig and Marshall, Tex. Bul. 76; Burns, Tex. Bul. 182; Knox, Jones, et al., Tex. Rpts. 1933, 1934; Quesenberry, U.S.D.A. Cir. 65.
103. Bray, La. Bul. 368; Tillman, Kidwell, and Singletary, La., Jour. Anim. Sci., 10, 1951, pp. 837–840; Robison, Ohio Bul. 607; see also: Dvorachek, Ark. Bul. 128; Dvorachek and Sandhouse, Ark. Bul. 142; Martin, Ark. Bul. 303; Hughes, Cal. Bul. 420; Bray, La. Bul. 242; Templeton, Miss. Rpt. 1924; Burk, Tex. Bul. 224; Williams and McConnell, Tex. Bul. 286; Warren and Williams, Tex. Bul. 313; Sheets and Semple, U.S.D.A. Misc. Pub. 132; Tirol, Philippine Agriculturist, 21, 1933, pp. 628–638.
104. Upp, La. Bul. 243.
105. Dvorachek, Ark. Buls. 221, 257.
106. Snell, Bray, Morrison, and Jackson, La. Bul. 389.
107. Bray, La. Bul. 368; see also: Dvorachek, Ark. Bul. 128; Martin, Ark. Bul. 303; Hughes, Cal. Bul. 420; La. Planter, 69, 1922, pp. 59–61; Bray, La. Bul. 242; Barnett and Goodell, Miss. Bul. 218; Templeton, Miss. Rpt. 1924; Williams and Warren, Tex. Bul. 313; Sheets and Semple, U.S.D.A. Misc. Pub. 132.
108. Summarized by Bray, La. Bul. 368.
109. Bray, La. Bul. 296.
110. Starkey and Salmon, S.C. Bul. 214; Barton, Ness, and Crampton, Macdonald Col., Canada, Tech. Bul. 4.
111. Noland and Gainer, Ark. Bul. 538; Noland and Ford, Ark. Farm Res., 3, 1954, No. 3; Ray, Ark. Farm Res., 4, 1955, No. 4.
112. Texas Bul. 724.
113. Rusoff and Frye, La., information to the author.
114. Buffum and Griffin, Colo. Bul. 75; Brown, Mich. Cir. Bul. 80; Wilson and Skinner, S.D. Buls. 80, 81, 86, 97; Wilson, S.D. Bul. 160; Olson, S.D. Bul. 264; Hackedorn, Sotola, and Singleton, Wash. Bul. 258; Faville, Wyo. Buls. 81, 85.

115. Osland, Maynard, Morton, and Brandon, Colo. Bul. 395, Press Bul. 80; Maynard and Brandon, Colo. Press Bul. 69; Goodearl and Moore, N.D. Bul. 303; Goodearl, N.D. Bul. 329; Christensen et al., N.D. Bul. 318; Dinusson, Bolin, Buchanan, and Richard, N.D. Bimo. Bul., 17, 1954, No. 2; Wilson and Skinner, S.D. Buls. 83, 86, 97; Wilson, S.D. Bul. 160; Wilson and Wright, S.D. Bul. 316; Wilson and Poley, S.D. Bul. 337.
116. Aubel, Kan. Cir. 287.
117. Sure, Ark., Jour. Agr. and Food Chem., 3, 1955, pp. 789–792.
118. Duncan, Hobbs, and Odom, Tenn. Farm and Home Sci., No. 12, 1954.
119. Grisdale, Ottawa, Canada, Expt. Farms, Bul. 51; Ottawa, Canada, Expt. Farms, Rpts. 1894, 1901.
120. N.J. Rpt. 1931; Hayward and Weld, Penn. Bul. 41; Penn. Bul. 170; Hills, Vt. Rpt. 1903.
121. Robison, Ohio Bul. 349; Penn. Bul. 170; Livesay and Stillwell, West Va. Bul. 213.

CHAPTER XXII

OTHER SEEDS AND THEIR BY-PRODUCTS

I. Soybeans, Soybean Oil Meal, and Other Soybean By-products

792. Soybeans.—In the discussion of soybeans as a forage crop in Chapter XVI it has been pointed out that in recent years they have become one of our most important crops. The largest acreage is grown in the heart of the corn belt, but soybeans are also raised extensively southward to the Gulf States. Over 85 per cent of the entire acreage of soybeans is grown for seed, chiefly for the production of soybean oil and soybean oil meal. The average yield of seed per acre is about 20 bushels of 60 lbs. each.

Soybeans are the richest in protein of all the common seeds used for feed, averaging 37.9 per cent. They are also high in fat, having 18.0 per cent, and they are rather low in fiber, with 5.0 per cent. In total digestible nutrients, they rank even above corn, chiefly because of their high fat content. Most black-seeded varieties of soybeans are somewhat lower in fat than the yellow-seeded varieties common in the corn belt.

Soybeans are rather low in calcium, with only 0.25 per cent. They have much less phosphorus than wheat bran, wheat middlings, cottonseed meal, or linseed meal, as they contain only 0.59 per cent. Like other seeds, soybeans lack vitamin D, and they have practically no carotene (vitamin A value). They are not rich in riboflavin, but have more riboflavin and thiamine than do the cereal grains. They are much higher than corn or oats in niacin.

For some unknown reason, feeding any large proportion of soybeans in a ration, at least for cattle, decreases the utilization of carotene or vitamin A and consequently increases the vitamin A requirement.[1] This is not of practical importance unless the ration is borderline in content of carotene or vitamin A. Soybean oil meal does not have this effect.

Soybeans should be ground for dairy cattle, but this is unnecessary for horses and sheep, and also for beef cattle if pigs follow the cattle to utilize the unchewed grain and beans in the droppings. To grind soybeans in some mills it is necessary to mix them with grain, as they tend to "gum-up" some mills, because of the high fat content. Ground soybeans are apt to turn rancid if stored long in warm weather. Because of the high fat content of soybeans, stock sometimes tire of them if fed too liberal amounts for long periods.

793. Value for non-ruminants increased by thorough cooking.—Numerous experiments have shown that the nutritive value of soybeans and of soybean oil meal for non-ruminants, such as swine and poultry, is much increased by proper cooking.[2] Such cooking greatly increases the availability and value of the protein for these animals and also destroys a substance, called the trypsin inhibitor, that depresses the growth of non-ruminants and prevents the action of the protein digestive enzymes, trypsin and erepsin.

Raw soybean protein therefore has a low value for pigs and poultry. Fortunately, properly cooked soybean oil meal or soybeans furnish protein that is equal or nearly equal in value to the protein of milk or fish meal. While thorough cooking greatly improves soybean protein for non-ruminants, too high heat or too prolonged cooking reduces the value, because it destroys or makes unavailable lysine or certain other amino acids.

The protein of soybeans is rather low in total amount of the sulfur con-

taining amino acids—methionine and cystine. However, this is ordinarily corrected by the fact that the cereal grains have a fair amount of these amino acids.

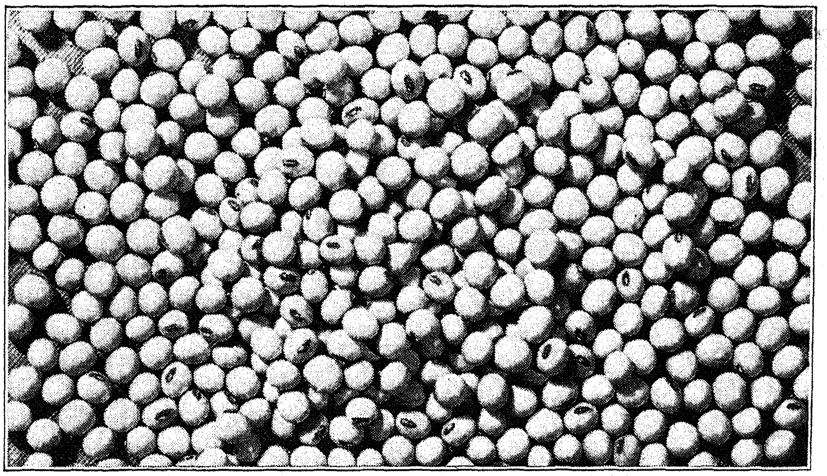
In the discussions of the use of soybeans for the various farm animals in this chapter, it is shown that, differing greatly from the results with swine and poultry, raw soybeans are a very satisfactory protein supplement for dairy cows, for beef cattle a year of age or older, for sheep, and for horses. It is pointed out later that for fattening calves, well-cooked soybean oil meal is decidedly superior to raw soybeans, while raw soybeans generally give good results as the protein supplement for older fattening cattle. (**800**)

794. Oil-milling methods.—In the processing of soybeans and other oil-rich seeds for the production of oil, three different methods are used: the hydraulic process, or so-called "old process"; the expeller process; and the solvent process.

In the hydraulic process the seed is crushed into flakes and thoroughly cooked by steam. Then the mass is formed into cakes wrapped in heavy cloth, and these are placed in hydraulic presses, where as much of the oil as possible is pressed out. The residue, which is in the form of hard cakes or slabs, is ground into meal or cracked coarsely into nut-size fragments.

In the expeller process the seed is cracked, dried, and then heated in a steam-jacketed apparatus. The oil is expressed in expellers, or screw presses, in which tremendous pressure is exerted by a worm shaft revolving in a horizontal barrel. In this process considerable heat is produced by the friction as the material passes through the expeller under the great pressure. This cooks the meal thoroughly, if the process is properly regulated. The residue, which is in flake form, is ground into meal, or may be put through machines which press it into pellets.

In the solvent process the seed is cracked, heated mildly, and rolled into thin flakes. The flakes next pass into an extracting tower where the oil is extracted by a volatile solvent. The residue is then heated and dried to remove all traces of the solvent. This solvent process removes the oil from the seed much more completely than either the hydraulic or the expeller process. For example, while expeller or hydraulic soybean oil meal



Soybeans Have Become One of Our Most Important Crops

Over 85 per cent of our acreage of soybeans is grown for seed, chiefly for the production of soybean oil and soybean oil meal.

usually has 4 to 5 per cent of fat or oil, solvent-process soybean oil meal may have less than 1 per cent.

In processing soybeans by the solvent method, the extracted soybean flakes must finally receive a special heat treatment, called "toasting," in a steam-jacketed apparatus, in order to cook them thoroughly. Otherwise, they will not be cooked enough to produce satisfactory results in feeding swine and poultry. After this, the flakes are ground to form soybean oil meal or may be pressed into pellets.

795. Soybean oil meal.—The production of soybean oil meal has increased so greatly in the United States during the past few years that it is now our most important high-protein supplement. During recent years our annual production of soybean oil meal has been well over 5,000,000 tons a year, or more than double the production of cottonseed meal.

Expeller- or hydraulic-process soybean oil meal is commonly guaranteed to contain 41 per cent protein, but sometimes the protein guarantee is 43 per cent or even higher. The 41-per cent grade contains 44.0 per cent protein, on the average, thus running well above the guarantee. Solvent-process soybean oil meal is usually sold with a guarantee of 44 per cent protein, and averages 45.7 per cent in protein content.

Expeller or hydraulic soybean oil meal of 41 per cent protein grade has an average of 4.8 per cent fat, while the solvent-process soybean oil meal has only 1.3 per cent fat. Soybean oil meal is lower in fiber than cottonseed meal or linseed meal. It ranks high in digestibility and has slightly more total digestible nutrients than cottonseed meal or linseed meal. Expeller or hydraulic soybean oil meal averages 77.9 per cent in total digestible nutrients, and although solvent-process soybean oil meal has much less fat, it is as high in total digestible nutrients.

Soybean oil meal is rather low in calcium, with an average of only 0.27 per cent for the expeller- or hydraulic-process product. It has much less phosphorus than there is in cottonseed meal or wheat bran, having an average of 0.63 per cent. Minerals are sometimes added to soybean oil meal to supply additional calcium and phosphorus, and the product is then sold under a trade name, or as mineralized soybean oil meal.

Like soybeans, soybean oil meal does not supply carotene or vitamin D. It is not rich in riboflavin, but has considerably more than corn or other grain. The niacin content is fairly high, and the thiamine content about like that of the cereal grains.

The taste of soybean oil meal indicates in a general way whether it has been cooked sufficiently to make it suitable for swine or poultry. If the soybean oil meal has a raw, "beany" taste, it has not been cooked enough for these classes of stock. Well-cooked hydraulic-process or expeller-process soybean oil meal has a pleasant nut-like taste and a light brownish or tan color. Properly-cooked solvent-process soybean oil meal may be lighter in color, and have no pronounced nut-like taste, but not a raw, "beany" taste. Chemical methods have been developed for determining whether soybean oil meal has been cooked sufficiently for feeding to poultry and swine.[3]

A few years ago certain oil mills began to use trichloroethylene instead of hexane, the usual solvent, in the solvent process. Though this solvent itself is not toxic, for an unknown reason some of the soybean oil thus produced was poisonous to cattle and certain other animals. The use of this solvent was therefore discontinued.

Because of the importance of soybean oil meal in livestock feeding, detailed information follows concerning its value and use for each class of farm animals. In general, it may be stated that soybean oil meal is one of our best protein supplements. For swine and poultry, properly cooked soybean oil meal ranks ahead of all other common protein supplements of plant origin, because of the high quality of its protein.

796. Dehulled solvent soybean oil meal.—Some solvent process soybean oil

meal is made from soybeans from which the hulls have been first removed. This dehulled solvent-extracted soybean oil meal is usually guaranteed to have 50 per cent protein. According to the definition of the Association of American Feed Control Officials, it should not have more than 3 per cent of fiber.[4]

Because of its high content of protein and low fiber content, this product is used in some high-energy mashes for chicks and broilers or in pig starters.

797. Soybean mill feed.—This is the by-product from the manufacture of soybean flour or grits and of dehulled soybean oil meal. It is composed chiefly of soybean hulls and has 29.5 per cent of fiber and only 15.7 per cent of protein. Soybean mill feed is therefore a low-grade feed, resembling hay in fiber content and value, and being far different from soybean oil meal.

The fiber guarantee of any such by-product should be noted carefully, as it will give an indication of its value in comparison with other feeds.

798. Soybeans for dairy cattle.—Ground soybeans are an excellent protein supplement for dairy cows, and in trials have been equal to linseed meal in value per ton[5] and slightly superior to cottonseed meal.[6] Even for dairy calves 2 to 3 months old at the start, ground soybeans were equal to linseed meal as the protein supplement in an Indiana test.[7]

Ground or cracked soybeans are well liked by dairy cattle when fed in such amounts as are needed to balance the ration, and are slightly laxative. In Iowa trials cracked soybeans were even satisfactory when fed as the only concentrate to dairy cows for long periods, some cows eating as much as 8.5 lbs. a day.[8] However, in Indiana experiments mixtures containing 50 per cent or more of ground soybeans were less well liked by cows than mixtures with a smaller proportion.[9]

As stated previously in this chapter, feeding to cattle a ration containing a large proportion of soybeans decreases the utilization of carotene or vitamin A. (**792**) For this reason, the vitamin A value of milk and the yellow color of butterfat may be decreased appreciably on such a ration, unless an abundance of good roughage is fed that is rich in carotene.[10] In Ohio experiments dairy cows were fed for over 3 years a concentrate mixture containing 23 per cent of ground soybeans as the only protein supplement, along with good hay and silage or else pasture.[11] The milk production equalled that on a ration containing soybean oil meal as the protein supplement, and the soybean ration did not appreciably lower the carotene or vitamin A content of the milk.

When the concentrate mixture contained 25 per cent or more of soybeans in the Indiana and Iowa trials, the fat percentage of the milk was generally increased. In 7 Indiana tests the fat test was 0.25 per cent higher on rations containing soybeans than on other rations with no soybeans. Feeding a large proportion of soybeans tends to produce soft butter, but the flavor of the milk is not injured by any ordinary amount of soybeans.[12] The effect on the character of the fat tends to decrease after a time.

799. Soybean oil meal for dairy cattle.—Soybean oil meal is one of the best protein supplements for dairy cattle, equaling linseed meal, cottonseed meal, or ground soybeans.[13] Because of the excellent quality of protein in soybean oil meal, if it is used as the chief protein supplement in a dairy calf starter, no protein supplement of animal origin is needed, such as dried skimmilk. (**1141**)

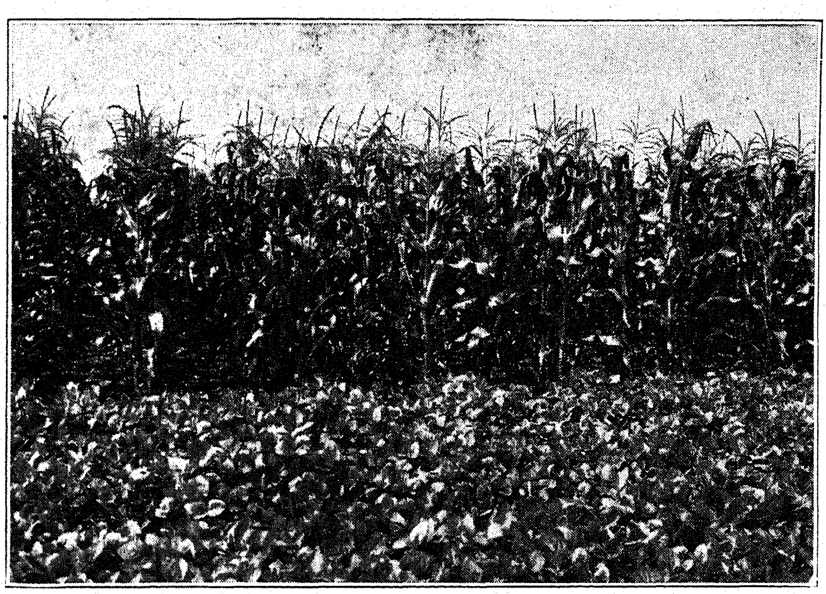
If the other feeds in the ration are low in fat, soybean oil meal made by the expeller process or the hydraulic process is preferable to solvent-process soybean oil meal, as it will help supply sufficient fat to make possible maximum milk and butterfat production. Because most of the oil has been removed from soybean oil meal, it does not affect the hardness of butter.

800. Soybeans for beef cattle.—In the soybean-growing districts soybeans are often used as the protein supplement for fattening cattle and for the breeding herd. Extensive experiments have shown that soybeans give somewhat better re-

sults as the protein supplement for fattening yearlings and older cattle than for fattening calves. This may be because calves must be fattened over a much longer period and often tire of the fat-rich soybeans during the latter part of the feeding period, or even tend to go "off feed."

In 28 experiments soybeans have been compared with soybean oil meal, cottonseed meal, or linseed meal as the only protein supplement for fattening value as the protein supplement, being worth 94 per cent as much per ton as cottonseed meal.[16]

Fattening cattle should not be fed more soybeans than are needed to balance the ration, as too large an allowance may be unduly laxative and may tend to throw the cattle "off feed." The amounts needed to balance various rations are shown in Appendix Table VII. Soybeans need not be ground for beef cattle which are followed by pigs.



SOYBEANS THRIVE WHERE CORN CAN BE GROWN

Soybeans are drouth resistant, are adapted to a wide range of soils, stand considerable frost, and do well on soil too sour for alfalfa.

two-year-old or yearling cattle.[14] The cattle fed soybeans as the supplement have gained as fast or nearly as fast as those fed the other supplements. In these many trials soybeans were worth slightly more per ton than soybean oil meal or cottonseed meal, and as much as linseed meal.

For fattening calves soybeans have been a decidedly less satisfactory protein supplement than soybean oil meal or linseed meal in 7 experiments, and worth considerably less per ton.[15] In 11 trials with fattening calves soybeans more nearly approached cottonseed meal in

801. Soybean oil meal for beef cattle.—Soybean oil meal is one of the best protein supplements for beef cattle, being excellent for fattening cattle and for the breeding herd. Because soybean oil meal is not high in fat, fattening cattle do not show the tendency to tire of it during a long feeding period, which sometimes occurs with soybeans. Also, soybean oil meal is only slightly laxative and does not produce scours when fed in considerably larger amounts than are needed to balance the ration.

In 20 experiments fattening cattle made equal gains when fed soybean oil

meal in comparison with cottonseed meal as the supplement.[17] The cattle fed soybean oil meal required a little less feed per 100 lbs. gain and sold for a few cents more per hundredweight, on the average. In these experiments the average net return would have been equal, if soybean oil meal had cost 28 per cent more per ton than cottonseed meal.

In Nebraska tests when a mineral mixture was fed to supply additional phosphorus, soybean oil meal was about equal to cottonseed meal as the protein supplement for beef calves wintered on prairie hay.[18] On the other hand, cottonseed meal produced slightly better results when the mineral mixture was not fed.

Soybean oil meal has not proven equal to linseed meal as the only protein supplement for fattening cattle. In 11 experiments cattle fed soybean oil meal as the supplement gained 0.1 lb. a day less than others fed linseed meal, required a little more feed per 100 lbs. gain, and sold for 13 cents less per hundredweight.[19] Taking all these seemingly small differences into consideration, it would have been necessary to buy soybean oil meal at only 67 per cent of the price of linseed meal to make an equal net return over cost of feed and cattle.

A small difference in the selling price of fat cattle makes considerable difference in the value of a protein supplement, because it applies to the entire weight of the cattle when marketed, and this difference in sale value must be charged against the rather small amount of supplement fed during the fattening period.

Solvent-process soybean oil meal has been fully equal to expeller-process or hydraulic-process soybean oil meal in feeding value in 8 tests with fattening cattle and 3 trials with calves being wintered.[20] The solvent-process product may sometimes be a trifle less palatable, however.

802. Soybeans and soybean oil meal for sheep.—Both soybeans and soybean oil meal are excellent protein supplements for sheep feeding. Experiments have shown that they are usually equal to linseed meal or cottonseed meal in value per ton.[21] There seems to be little choice between soybeans and soybean oil meal for feeding sheep, since the results with these two supplements have been practically the same, on the average, in 10 trials with fattening lambs.[22] It does not generally pay to grind soybeans for sheep.

If not much higher in price per ton than corn, soybean oil meal can be used economically as the only concentrate for fattening lambs fed roughage low in protein.[23]

803. Soybeans and soybean oil meal for horses and mules.—Both ground soybeans and soybean oil meal are very satisfactory protein supplements for horses and mules. Not more than 1 lb. per head daily of either of these feeds is needed to balance any usual ration for horses and mules. Soybeans should not form over one-third the concentrate mixture, else they may cause digestive trouble, owing to their heavy nature. Farmers have reported that feeding a small amount of soybeans to horses in the spring seems to have the same effect as linseed meal, in making their hair smooth and sleek.[24]

804. Soybeans for swine.—Soybeans have very definite limitations for swine feeding. It is therefore wise for soybean growers to exchange soybeans for soybean oil meal to feed to swine, unless the price of soybean oil meal is considerably higher.

First of all, if growing and fattening pigs are fed soybeans as the only protein supplement to grain and the ration contains more than about 10 per cent of soybeans, the pork is apt to be soft.[25] If pigs in dry lot weigh at least 125 lbs. and pigs on pasture at least 70 lbs. before soybean feeding is begun, and if the amount of soybeans is no greater than is needed to balance the ration, satisfactory carcasses are usually produced.

The second limitation is that for pigs not on good pasture raw soybeans are decidedly inferior in nutritive value to soybean oil meal or to well-cooked

soybeans.[26] Cooking soybeans involves considerable labor and expense.

Except for the softening effect on the carcass, raw soybeans, fed as the only protein supplement, give better results with well-grown pigs than with young pigs, and are more satisfactory for pigs on pasture than for those in dry lot. For example, in 33 experiments on first-rate pasture, pigs fed raw soybeans and minerals as the supplements to corn gained 1.43 lbs. a day, in comparison with 1.54 lbs. for others fed soybean oil meal or tankage instead of soybeans. In these experiments, not considering the difference in rate of gain and the danger of producing soft pork on the soybean ration, 100 lbs. of soybeans were equal to 87 lbs. soybean oil meal plus 24 lbs. corn,[27] or to 60 lbs. of tankage plus 37 lbs. corn.[28]

Raw soybeans are decidedly inferior to soybean oil meal or cooked soybeans for pregnant sows or those nursing litters.[29]

Soybeans that have been thoroughly roasted or otherwise cooked produce satisfactory gains when fed with corn and a calcium and phosphorus supplement, even to pigs not on pasture.[30] However, cooking the soybeans does not at all prevent the softening effect on the carcass. Also, roasted soybeans are so palatable to pigs that, when the soybeans are self-fed, the pigs will eat much greater amounts than needed to balance the ration. If a mixture of shelled corn and the proper proportion of roasted soybeans is fed, the pigs will sort out the soybeans from the corn. It is therefore necessary to hand-feed the roasted soybeans, or to self-feed a mixture of suitable amounts of ground corn and ground soybeans.

In using soybeans as the protein supplement for swine, it is important to provide a mineral mixture supplying both calcium and phosphorus, even for pigs on good pasture. In the case of swine not on pasture, legume hay should be included in the ration, if possible, as an insurance against lack of vitamins. There is no need of grinding soybeans for swine.

Missouri tests show that feeding pigs a ration containing 25 per cent or more of soybeans increases the tendency of the pork to become rancid on storage in a freezer.[31]

When pigs are used to hog down a field of ripe soybeans, they make satisfactory gains if supplied with a mineral mixture and fed a limited amount of corn in addition. However, the carcasses will be decidedly soft.

805. Soybean oil meal for swine.—Soybean oil meal that has been properly cooked in the manufacturing process is the best of all common protein supplements of plant origin for swine feeding. For pigs and other swine on good pasture it gives excellent results when used as the only protein supplement, if a mineral supplement is provided to supply additional calcium and phosphorus.

In each of 19 trials one lot of pigs, averaging 64 lbs. in weight at the start, was full-fed corn on good pasture, with soybean oil meal and with minerals to supply additional calcium and phosphorus, while another lot was fed tankage or meat scrap as the supplement.[32] The pigs fed soybean oil meal equalled those fed tankage or meat scrap in rate of gain, but they required a trifle more feed per 100 lbs. gain. On the average, 100 lbs. of soybean oil meal equalled 43 lbs. tankage plus 44 lbs. corn, but minus 3 lbs. mineral mixture, in feeding value.

Soybean oil meal is also very satisfactory as the only high-protein supplement to grain for well-grown pigs not on pasture, if legume hay is included in the ration, as well as a calcium and phosphorus supplement. However, the experiments reviewed in Chapter XXXIV have shown that young pigs in dry lot, placed at weaning time on such a ration as corn, soybean oil meal, and minerals, may not thrive even when 5 per cent of good-quality alfalfa hay is included in the ration. Some may become runts or be unable to walk normally. Similarly, if brood sows are raised in dry lot on such rations and continued on them during pregnancy, many of the pigs may be weak at birth or the sows may be un-

able to provide enough milk for them. Poor results sometimes occur even on rations containing protein supplements of animal origin, but are more frequent when no meat scrap, tankage or fish meal is fed. These troubles are due to deficiencies of certain vitamins.

Such troubles may be prevented by raising the sows on good pasture and by including 15 per cent of good alfalfa hay or other legume hay in their winter rations. Pigs will not generally show these deficiencies if they are well started on good pasture before they are placed in dry lot, and are then fed such rations only after they have reached a weight of 60 to 75 lbs.

Soybean oil meal has a great advantage over soybeans as a supplement for fattening pigs, because it does not produce soft pork when fed in any ordinary amount. Properly cooked soybean oil meal is liked so well by pigs that if it is self-fed, free-choice, as the supplement to grain, they will often eat much more of the soybean oil meal than they need to balance their ration. To prevent this, the soybean oil meal can be hand-fed in the proper amount, or some less palatable feed, such as ground alfalfa hay, can be mixed with it.

Particularly good results are secured when soybean oil meal is used in combination with the protein supplements of animal origin, as in a trio-type mixture. Various desirable combinations are discussed in Chapter XXXIV.

Well-cooked soybean oil meal is of approximately the same value for swine, no matter whether made by the expeller process, the solvent process, or the hydraulic process. In 12 experiments toasted solvent-process soybean oil meal has been compared with expeller-process soybean oil meal as the supplement to corn for pigs on pasture or in dry lot. A mineral mixture was fed in addition and alfalfa hay was usually included in the rations for the dry-lot pigs.[33] On the average, the pigs fed solvent-process soybean oil meal gained 1.23 lbs. and those fed the expeller-process product just a trifle more, 1.25 lbs. Each 100 lbs. of the solvent-process soybean oil meal equalled 108 lbs. of expeller-process soybean oil meal minus 19 lbs. of corn in feeding value.

806. Soybean oil meal and soybeans for poultry.—Among common feeds, soybean oil meal which has been thoroughly cooked in the manufacturing process is the best substitute for protein supplements of animal origin in poultry feeding. Raw soybeans or even cooked soybeans are much less satisfactory than soybean oil meal and have a considerably lower value. Soybeans should therefore be used for poultry only when better protein supplements are not readily available.

Numerous experiments have been conducted to find the extent to which soybean oil meal can be used satisfactorily in poultry rations to replace such supplements as fish meal, meat scrap, and milk by-products.[34] These investigations have shown that in using soybean oil meal as the chief protein supplement it is especially important to correct the deficiencies of calcium and riboflavin. Also, a phosphorus supplement should be added to the ration, if necessary, as soybean oil meal is only fair in phosphorus content. If the ration is thus properly supplemented, soybean oil meal gives excellent results when used to replace at least one-half of the animal protein needed to balance rations for chicks, growing pullets, or laying hens.

When there is a shortage of animal-protein supplements, as occurred in World War II, satisfactory results are generally secured when soybean oil meal replaces a considerably larger part of the feeds of animal origin. If great care is taken to supply proper amounts of calcium, phosphorus, riboflavin, and other B-complex vitamins, reasonably good egg production and growth of chicks can be secured when soybean oil meal replaces all the fish meal, meat scrap, or tankage in usual rations. However, for rapid growth and fattening of broilers and for high hatchability of eggs, a minimum amount of such animal feeds should be included in the ration. Too large a proportion of soybean oil meal in the start-

ing mash for chicks may cause trouble from "pasting up," in which the feces stick to the down.

In most tests, solvent-process soybean oil meal that has been properly cooked has been equal to expeller-process or hydraulic-process soybean oil meal that has also been well cooked.[35] Soybean oil meals of the same type may vary in value, depending on the care taken by the manufacturer to control the temperature to which the soybean oil meal is heated. Sufficient cooking is essential, but overcooking is detrimental.

If ground raw soybeans are used for poultry, they had best be used to replace not more than one-third of the animal-protein supplements.[36] Soybeans give better results when fed to poultry on good pasture than for birds in confinement. Thorough cooking of soybeans by roasting or boiling increases their value for poultry, but cooked soybeans are not so satisfactory as soybean oil meal. Sprouting soybeans increased their value in a New Jersey test but did not improve them appreciably in a Maryland trial.[37] In any event, sprouting requires considerable labor and trouble.

Colorado studies show that raw soybeans may have a tendency to produce goiter in chicks, unless iodine is added to the ration.[38]

II. Cottonseed and Cottonseed By-products

807. Importance of the cotton crop.—Cotton (*Gossypium hirsutum*) ranks next to corn and wheat in value in the United States, and is the most important southern crop. Cotton is grown primarily for the fiber, but cottonseed meal and cake, secured in the production of oil from cottonseed, are among our most important feeds. Also, cottonseed hulls are one of the most common roughages in the South.

During recent years about 2,400,000 tons of cottonseed meal and cake and 1,300,000 tons of cottonseed hulls have been produced a year in the United States. From each ton of cottonseed there are secured approximately the following: Cottonseed cake or meal, 954 lbs.; crude oil, 303 lbs.; hulls, 514 lbs.; and linters, or short fiber, 110 lbs.; with dirt and loss in manufacturing amounting to 119 lbs.[39]

808. Manufacture of cottonseed meal and cake.—At the oil mills, after the cottonseed has been cleaned and more or less of the short lint covering the seed has been removed, the leathery hulls of the seed are cut by machines, so the kernels can drop out. The kernels are separated more or less completely from the hulls by shakers and beaters, containing metal screens. After the kernels are crushed, as much of the oil as possible is removed by one of the oil-milling methods. (794) The residue after most of the oil is removed is cottonseed meal or cake.

Until recently, the hydraulic method was commonly used in processing cottonseed, but now the expeller method is used extensively, and some mills use the solvent method or a combination of preliminary treatment in expellers, or screw presses, followed by solvent extraction (called the prepress solvent method).

The large cakes of cottonseed cake produced in the hydraulic method are ground to form cottonseed meal, or broken into pieces of pea or nut size for sale as cottonseed cake. Some cottonseed meal is put through pelleting machines to produce pellets or cubes of various sizes. For feeding outdoors, especially for use on the western ranges, cottonseed cake or pellets are preferred to cottonseed meal, as they are not scattered by the wind. In the eastern and central states and for feeding to dairy cattle cottonseed meal is generally used. Since most of the product is fed in this country as cottonseed meal, and also since the meal and cake have the same general value, the term cottonseed meal will be commonly used in this volume in referring to both cottonseed meal and cottonseed cake.

The following sizes of cottonseed cake are made in this country: *Nut-size cake,* consisting of pieces from three-fourths to 1.5 inches in diameter; *sheep-size cake,* from five-eights to seven-eights inch; *pea-size cake,* from three-eights to

five-eights inch; and *pebble-size cake,* under three-eights inch in diameter.

809. Grades of cottonseed meal or cake.—Because cottonseed meal and cake are used chiefly as protein supplements, they are graded and sold on the basis of the guaranteed protein content, in addition to the general quality. To conform to the official definitions of the Association of American Feed Control Officials, cottonseed meal or cake must contain at least 36 per cent of protein and must be composed principally of the kernel, with only such portion of the hull as is necessary in the manufacture of oil.[4] If the product has less than 36 per cent of protein, it must be sold as cottonseed feed.

Cottonseed meal is classed either as *prime quality* or *off quality.* According to the official definition, *cottonseed meal, prime quality* must be finely ground, not necessarily bolted, be free from excessive lint, must not have a sour, musty, or burnt odor, and must contain not less than 36 per cent of protein. It must be designated and sold according to its protein content. For example, prime-quality cottonseed meal guaranteed to contain 41 per cent protein must be designated as "41 per cent protein cottonseed meal, prime quality." Cottonseed meal that is not high grade in odor or texture is designated as "off quality."

Because of the variation in composition, cottonseed meal or cake should always be purchased on definite guarantees, not only of protein content but also of fat and fiber. The grades with lower protein content not only supply less protein but are also higher in fiber, because the hulls are usually removed less completely. Such meal therefore furnishes less total digestible nutrients than that which has 41 per cent or more of protein.

The cottonseed raised in certain sections of the Southwest, especially in Texas, is higher in protein than the seed produced in other cotton-growing districts. For this reason, 41 per cent protein cottonseed meal from such seed usually contains slightly more hulls and is therefore a little higher in fiber and

PICKING A CROP OF COTTON

Cotton is by far the most important crop in the southern states. The cottonseed meal and cake produced in the processing of cottonseed for oil rank next to soybean oil meal in importance among the high-protein supplements used for stock feeding. (From Ward, Educational Service, National Cottonseed Products Association.)

lower in feeding value than cottonseed meal containing 41 per cent protein from districts where cottonseed is lower in protein.

810. Composition and nutritive properties.—Cottonseed meal of the usual grades contains 41 per cent protein or more, thus having nearly as much as soybean oil meal. It supplies protein of satisfactory quality for cattle, sheep, or horses, when used as the only or the chief protein supplement. However, cottonseed meal does not furnish protein of high quality for swine or poultry, chiefly because it is rather low in lysine. For them, it should therefore be used in combination with such supplements as tankage, meat scrap, fish meal, milk by-products, or soybean oil meal. Such combinations will not only provide protein of better quality, but will also prevent injury from gossypol, which is discussed later.

In Oklahoma comparisons of cottonseed meals made by the solvent process and the hydraulic process, there were no appreciable differences in digestibility or in the value of the protein for beef steers or lambs.[40]

Most of the cottonseed meal produced by the hydraulic or expeller methods has 5 per cent fat or slightly more. The fat content was somewhat higher before modifications had been made in these methods which made possible more complete removal of the fat, or oil. Solvent-process cottonseed meal is much lower in fat.

High-grade cottonseed meal supplies slightly less total digestible nutrients than does linseed meal. The solvent-process meal is somewhat lower than the expeller-process or hydraulic-process meal, because of the lower fat content.

Cottonseed meal is one of the richest feeds in phosphorus, containing about 1.0 per cent or more. In contrast to the high phosphorus content, it has only about 0.2 per cent calcium. Like other seed products, cottonseed meal lacks vitamin D, and it also has little or no carotene (vitamin A value). These lacks can readily be made good by including in the ration a sufficient amount of well-cured legume hay or mixed hay high in legumes. If grass hay, such as timothy or prairie hay, is of excellent quality, it will supply these necessary nutritive factors, except that it may not furnish enough calcium, unless grown on soil rich in lime. Cottonseed meal has a fair content of the B-complex vitamins.

Cottonseed meal tends to produce milk fat of a high melting point and hard body fat. It thus helps to overcome the tendency of peanuts and soybeans to produce soft pork. Cottonseed meal may be slightly constipating in effect, but not noticeably so when it is fed with such feeds as legume hay or silage. This effect may be advantageous when considerable amounts of very laxative feeds are used, such as beet molasses or sugar beet tops.

811. Cottonseed meal as a feed.—Cottonseed meal is one of the best protein supplements for dairy cows, beef cattle, and sheep. For swine and poultry the ordinary kinds of cottonseed meal should be fed in strictly limited amounts, because of the danger of injury from a substance called gossypol which ordinary cottonseed meal contains.

Raw cottonseed contains appreciable amounts of gossypol, the amount varying considerably with the climate and the soil. Gossypol is poisonous to certain kinds of animals if consumed in sufficient amounts. Fortunately, in the heating that occurs in the process of oil manufacture much of the gossypol is changed into a substance (called d-gossypol, or bound gossypol) which is much less poisonous.

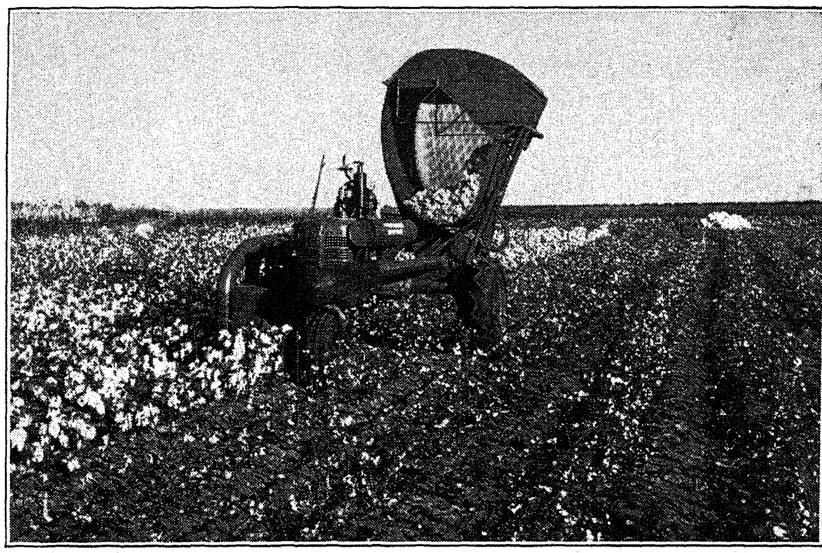
Extensive experiments have proved that cattle over 3 or 4 months of age may safely be fed large amounts of ordinary cottonseed meal continuously for long periods, if care is taken to provide plenty of high-quality hay or good pasturage.[41] Such roughage makes good the lack of carotene and other possible deficiencies in the cottonseed meal and the other concentrates usually fed.

These investigations have proved that in the case of cattle these deficiencies are the primary cause of the so-called "cottonseed-meal poisoning" which often occurs when stock are

heavily fed on cottonseed meal and roughage low in vitamins and calcium. Cattle are not affected by the amount of gossypol usually present in cottonseed meal, or even in cottonseed. Thus, in Oklahoma experiments dairy cows have not been injured when they have been fed as much as 10 lbs. of cottonseed meal per head daily for 3 years with good roughage, but without any pasture.[42]

ing. Sheep may be fed as much ordinary cottonseed meal as is needed to balance their rations, but should not be fed large amounts continuously for long periods. However, as is shown later, lambs have been fattened satisfactorily for the usual length of time on cottonseed meal as the only concentrate, fed with plenty of legume hay. (**816**)

Swine, poultry, and young calves are injured by an appreciable amount of free gossypol in the ration. Horses and mules must also be fed ordinary cottonseed meal with caution. The following articles state the proportions of ordinary cottonseed meal that can be fed safely to these classes of stock.



A MECHANICAL COTTON PICKER

Cotton pickers have been recently developed which greatly reduce the expense of harvesting the crop. (From Ward, Educational Service, National Cottonseed Products Association.)

Symptoms similar to the so-called "cottonseed-meal poisoning" were produced in some of these experiments when cattle were fed rations low in carotene but which included no cottonseed products whatsoever. Provided the injury on such a ration as cottonseed meal and hulls had not progressed too far, the animals could be cured rather rapidly by feeding cod-liver oil, good legume hay, or fresh green forage.

For calves under 3 to 4 months of age it is best not to use more than about 20 per cent of ordinary cottonseed meal in the concentrate mixture. A larger proportion is apt to cause gossypol poisoning.

The investigations which have proved that with good roughage cottonseed meal can be safely fed to dairy cows and other cattle, except young calves, in large amounts and even as the only concentrate, are of especial importance in the southern states. There cottonseed meal is frequently the cheapest source not only of protein but also of digestible nutrients. Under these conditions it is

often economical to feed cottonseed meal as the only concentrate to dairy cows and beef cattle, or at least in considerably larger amounts than are needed to balance the ration in protein content.

812. Low-gossypol cottonseed meal.—Cottonseed meal produced by the usual methods, no matter whether hydraulic, expeller, or solvent, varies widely in content of free gossypol. In North Carolina studies, for example; 114 samples of cottonseed meal tested had an average of 0.093 per cent, with the wide range of 0.030 to 0.208 per cent.[43] To be used with safety in any large proportion in swine rations, cottonseed meal should not have more than 0.04 per cent free gossypol, and in poultry rations not more than 0.02 per cent.

Considerable research has therefore been conducted, especially by the Southern Regional Laboratory of the United States Department of Agriculture, to develop practical methods of processing by which cottonseed meal can be made that will uniformly have so little free gossypol that it can be safely fed in large amounts to swine and poultry.[44]

In some of the experiments thus far conducted, low-gossypol cottonseed meal has been satisfactory and has produced no injury when fed as the only protein supplement to pigs.[45] However, in other trials the results have not been good.[46]

By treating ordinary cottonseed meal several hours before feeding it with a solution containing 3.4 lbs. of ferrous sulfate per 100 lbs. of cottonseed meal, it was made safe for pigs in Ohio experiments.[47] This treatment destroys the free gossypol or changes it into the inactive form. In Mississippi tests merely mixing 0.3 lb. of dry ferrous sulfate with each 100 lbs. of a feed mixture high in cottonseed meal made it safe for pigs.[48]

813. Cottonseed meal for dairy cattle.—Cottonseed meal is one of the most widely-used protein supplements for dairy cows, because it is very rich in protein, the protein is of satisfactory quality for ruminants, and the feed is well liked by cattle. Cottonseed meal is usually the cheapest source of protein in the southern states, and is often one of the most economical protein supplements in the North.

The experiments reviewed previously have shown that no definitely poisonous effects are produced even when cottonseed meal is fed as the only concentrate to cows for long periods, provided the roughage is of first-class quality. However, it is not wise to feed such a ration unless necessary. Instead, cottonseed meal should ordinarily be combined with grain and other feeds in the usual type of dairy concentrate mixture.

In Oklahoma and South Carolina experiments the feeding of cottonseed meal as the only concentrate for long periods lowered the fat content of the milk and also the solids-not-fat content.[49] Also, in the South Carolina trials such feeding of cottonseed meal for a long time seemed to have a detrimental effect on the health and reproduction of high-producing cows.

If cottonseed meal or cottonseed form too large a part of the concentrates fed cows, the butter is apt to be hard, sticky, and tallowy.[50] In addition, an abnormally long time is required for churning. This effect is reduced when the cows have silage or pasture. Contrary to the opinion sometimes expressed, heavy feeding of cottonseed meal has not increased the tendency to mastitis in the cows, or made the trouble more severe in the case of cows affected with the disease.

While cottonseed meal is not quite so palatable as linseed meal, it is well liked by cattle. Since it does not have the conditioning effect of linseed meal, many dairymen prefer to use both of these feeds as sources of protein in a concentrate mixture, rather than to use cottonseed meal as the only supplement. Wheat bran and soybean oil meal are also excellent feeds to use along with cottonseed meal. Even though the cost may be increased by furnishing this greater variety, the practice may be preferable, especially for cows of high productive capacity.

In Indiana trials cottonseed meal, linseed meal, and gluten feed were compared as supplements to a ration of

ground corn, corn silage, and legume hay.[51] The amount of each supplement was adjusted so that all rations furnished the same amount of protein. Thus fed, the production on the cottonseed-meal ration was fully as high as on the others. In a Virginia trial cottonseed meal for dairy cows was worth about 90 per cent as much as corn gluten meal, which is appreciably higher in digestible protein and in total digestible nutrients.[52]

When cottonseed meal is cheaper per ton than grain, as is sometimes the case in the South, it is economical to include more of it in the concentrate mixture than is needed to balance the ration. When the proportion of cottonseed meal in the concentrate mixture was increased from 11 per cent to about 50 per cent in Oklahoma experiments, the milk production was slightly higher.[53] Each 100 lbs. of additional cottonseed meal was worth 10 per cent more than the mixture of corn, oats, and wheat bran which it partly replaced.

Ordinary cottonseed meal may be used satisfactorily in a concentrate mixture for calves, if the mixture does not contain more than about 20 per cent of cottonseed meal and if the calves are supplied with good roughage, high in carotene. For example, in South Carolina experiments good results were secured with a calf meal consisting of 20 lbs. cottonseed meal, 39 lbs. ground yellow corn, 40 lbs. ground oats, and 1 lb. salt.[54] After calves are 3 to 4 months old, they may be fed larger proportions of cottonseed meal with safety. As the chief protein supplement in a calf starter, cottonseed meal is less satisfactory than soybean oil meal, because the quality of the protein is not so good.[55]

Too large a proportion of cottonseed meal of the usual kinds, even 40 per cent, in a mixture for calves is dangerous.[56] Holstein calves seem to be more susceptible to cottonseed meal toxicity than Jerseys.

In a Mississippi experiment a ration of cottonseed meal as the only concentrate with hay and silage was not satisfactory for dairy bulls, while the results were good on a mixture of one-third each of cottonseed meal, ground corn, and ground oats.[57]

814. Cottonseed meal or cake for beef cattle.—In this country cottonseed meal and cake are used extensively for beef cattle. They are very satisfactory supplements and are so rich in protein that only relatively small amounts are needed to balance rations low in this nutrient. In addition, cottonseed meal and cake are so high in phosphorus that they serve as phosphorus supplements, as well as protein supplements.

It is shown in Chapter XXVIII that when the proper amount of a high-protein supplement like cottonseed meal is added to a ration deficient in protein for fattening cattle, each 100 lbs. of the supplement will usually be equal in value to 250 to 300 lbs. of corn or other grain. Not only will less feed be required for each 100 lbs. gain on the properly balanced ration, but also the cattle will reach a better finish and consequently sell for a higher price.

The experiments summarized elsewhere in this chapter show that when cottonseed meal or cake is used as the only protein supplement to balance the usual rations for fattening cattle, it is worth decidedly less per ton than linseed oil meal or soybean oil meal. (**831, 801**) However, when cottonseed meal is combined with linseed meal, the combination is worth about as much as linseed meal.

When added to a ration that is somewhat too laxative, cottonseed meal or cake is superior to linseed meal as the supplement for fattening cattle, because it tends to counteract the laxative effect. For example, in Colorado tests cottonseed cake was a better supplement than linseed meal for fattening cattle which were fed liberal amounts of wet beet pulp and also beet molasses.[58]

Cottonseed cake and pellets are widely used as the protein supplement for beef cows or growing cattle being wintered on the range, 1 lb. per head daily being a common allowance. For this purpose cottonseed cake or meal has been about equal to soybean oil meal or linseed meal in Kansas and Mississippi

experiments, and somewhat lower in value in Oklahoma trials.[59]

To avoid wastage, cottonseed cake or pellets are generally used instead of cottonseed meal for beef cattle under ranch conditions and for fattening cattle in western feed lots where little or no shelter is provided. In feeding cottonseed cake as a winter supplement for range cattle, a common practice is to distribute it on the ground, the larger sizes of cake being preferred. Sometimes a mixture of cottonseed meal and salt is self-fed, the proportion of salt being adjusted so that the cattle will eat the desired amount of meal. (**1170**) It makes little difference whether cottonseed cake or meal is used when it is fed under shelter and in feed bunks.

In several experiments cottonseed cake has been compared with alfalfa hay as a supplement for calves that were being wintered on non-legume roughages. In these tests each 100 lbs. of cottonseed cake, fed at the rate of 1 lb. per calf daily, has equalled about 300 lbs. of alfalfa hay in actual feeding value. Where cottonseed cake or meal has been compared with grain as a supplement to non-legume roughage for wintering cattle in similar experiments, it has required about 2 lbs. of grain to take the place of 1 lb. of cottonseed meal.

In 2 Oklahoma and 3 Texas trials with fattening cattle solvent-process cottonseed meal as the protein supplement produced slightly less rapid gain than hydraulic-process cottonseed meal.[60] Somewhat more feed was required per 100 lbs. gain with the solvent cottonseed meal, and it was worth decidedly less per ton than the hyraulic meal.

815. Feeding large amounts of cottonseed meal.—In the southern states cottonseed meal is often cheaper per ton than corn or other grain, and it is then frequently fed to fattening cattle as the only or the chief concentrate. If care is taken to provide an ample supply of carotene and of calcium, cattle can ordinarily be fed large amounts of cottonseed meal with good results, and without any injury whatsoever. Well-cured hay, good silage, or green pasture all supply liberal amounts of carotene. Unless a reasonable amount of legume forage is fed, a calcium supplement should be supplied.

If cottonseed meal is lower than grain in price per ton, it is important to know what its relative value is in comparison with corn or other grain, when more is fed than is required to balance the ration. Several experiments have shown conclusively that the gains of fattening cattle are generally not increased by feeding a larger proportion of cottonseed meal than is needed. Also, when cottonseed meal is fed as a grain substitute, each 100 lbs. of cottonseed meal fed beyond the amount needed to balance the ration is worth only about as much as 96 lbs. of corn,[61] or a trifle less than 100 lbs. of ground barley.[62]

If somewhat more cottonseed meal is added to a ration that does not contain quite enough of the meal to balance the ration fully, its value will be higher than that of grain. For example, in 2 Texas comparisons calves fed 3.6 lbs. per head daily of cottonseed meal, with milo grain and low-protein roughage, gained slightly more than others fed 1.6 lbs. cottonseed meal.[63] The additional amount of cottonseed meal was worth considerably more than milo, pound for pound.

In some experiments in which different amounts of cottonseed meal have been fed, the gain has been much more rapid on the larger allowances. However, in these trials the total amount of concentrates (grain plus cottonseed meal) has been greater. The increase in the rate of gain was thus due to the larger amount of total concentrates, and not to any superiority of cottonseed meal over grain, when fed merely as a grain substitute.

Since legume hay is rich in protein, it is best to use it in combination with such roughage as corn or sorghum silage or fodder or else cottonseed hulls for fattening cattle that are fed protein-rich cottonseed meal as the only or the chief concentrate. In Texas trials very poor results were secured when peanut or alfalfa hay was fed to steers with 5 lbs. of cottonseed meal per head daily.[64] When

shelled corn was substituted for a part of the cottonseed meal or when prairie hay was fed in place of the legume hay, the gains became normal.

Cottonseed meal or cake should not ordinarily be used as the only concentrate for fattening calves, as they then tend to grow rather than fatten.[65] The results are better when they are fed not more than 8 to 10 lbs. of cottonseed meal per head daily, along with some grain.

Years ago the most common ration for fattening cattle in the South was cottonseed meal and cottonseed hulls, without any hay or silage. On this restricted ration cattle will usually make satisfactory gains for 2 or 3 months, but later they are apt to become unthrifty and suffer from the effects of the vitamin deficiency. This can be prevented by adding to the ration enough well-cured hay or good silage.

Therefore, for breeding cattle or for fattening cattle which are to be fed for several months, it is important to feed carotene-rich roughage along with a ration of cottonseed meal and hulls. Even in the case of cattle that are to be fattened for only 100 days or less, better results will usually be secured if a limited amount of good hay or silage is supplied.

816. Cottonseed meal or cake for sheep.—Cottonseed meal or cake is an excellent protein supplement for fattening lambs or for breeding sheep. Differing somewhat from the results with fattening cattle, cottonseed meal is practically equal to linseed meal or soybean oil meal for fattening lambs, if considerable legume hay is fed and if no more of the supplement is used than is actually needed. Since high-grade cottonseed meal is richer than linseed meal in protein, slightly less of it is required to balance a ration.

In 19 experiments cottonseed meal has been directly compared with linseed meal as the protein supplement to rations of corn grain and legume hay, with corn silage in addition in some cases.[66] The lambs fed cottonseed meal have made about as rapid gains as those fed linseed meal and there has been no appreciable difference in the amounts of feed required per 100 lbs. gain or in the selling price of the lambs. On the other hand, in 6 comparisons in which only a trifle of legume hay was fed with corn silage and oat straw as the chief roughages, cottonseed meal was worth about 88 per cent as much per ton as linseed meal.[67]

Cottonseed meal is excellent as the only protein supplement for wintering breeding ewes. In Oklahoma tests the results were satisfactory when as much as 0.5 lb. per head daily was fed with prairie or alfalfa hay.[68]

In the southern and southwestern states cottonseed meal, when low in price, is sometimes fed as the only concentrate to fattening lambs. If more cottonseed meal is fed than is needed to balance the ration, the additional amount is usually worth no more per pound than corn or other grains, and may be worth even less. In 4 Texas trials fattening lambs fed 1.2 lbs. cottonseed cake a day, with alfalfa hay for roughage, gained slightly less than others fed sorghum grain, alfalfa hay, and 0.16 lb. cottonseed cake.[69] Each 100 lbs. of additional cottonseed cake fed the first lots was worth only about 90 per cent as much as sorghum grain. The results were similar in Oklahoma trials in which fattening lambs were fed a large amount of cottonseed meal and a little corn, with alfalfa hay for roughage.[70]

When sheep are fed large amounts of cottonseed meal, there is danger of "cottonseed meal injury," unless they get plenty of good legume hay or other roughage rich in carotene. For example, lambs can be successfully fed cottonseed meal as the only concentrate with alfalfa hay for 90 to 100 days, but when cottonseed meal has been fed with cottonseed hulls as the only roughage for the entire fattening period, some lambs have died.[71]

817. Cottonseed meal for horses and mules.—Cottonseed meal is often used, especially in the South, as the protein supplement for horses and mules, and gives satisfactory results if not more than about 1 to 1.5 lbs. are fed daily per

1,000 lbs. live weight.[72] Sometimes even larger amounts have been fed successfully.[73]

When cottonseed meal is added to a ration low in protein, it is worth considerably more per pound than corn or other grain. Such balancing of the ration improves the condition and appearance of the horses or mules. Using cottonseed meal as a large part of the concentrates is not safe, as it may cause serious digestive disturbances because of its heavy nature. Also, it may be poisonous when too much is fed. Only good-quality cottonseed meal should be fed to horses or mules.

If more than 1.0 to 1.5 lbs. daily of cottonseed meal are fed, it is a good plan to mix it with a bulky feed, such as oats, bran, or corn-and-cob meal. It is best to feed not over one-fourth pound per head daily at first and then gradually to increase the allowance as the horses become accustomed to it.

818. Cottonseed meal for swine.—It is not safe to use ordinary cottonseed meal as the only protein supplement in swine feeding, because of the danger of gossypol poisoning. However, excellent results are secured when the amount of cottonseed meal is strictly limited and it is combined with supplements which supply protein of better quality. When pigs are fed soybeans or peanuts, the fact that cottonseed meal tends to make hard fat may be of distinct advantage in counteracting the effect of feeds, such as soybeans and peanuts, which produce soft pork.

Extensive investigations, especially experiments at the Ohio and Texas Stations, have shown that swine rations should not contain more than about 9 to 10 per cent of cottonseed meal and that they should provide protein of good quality and plenty of vitamins and calcium.[74] When thus fed cottonseed meal is even satisfactory in rations for brood sows. If too much cottonseed meal is fed, disaster may result, even when the other feeds in the rations supply an abundance of carotene and calcium.

In some cases pigs have been fed rations containing as much as 30 per cent cottonseed meal without injury, because the cottonseed meal happened to be low in gossypol. However, feeding such a ration is very hazardous.

A combination of one-half to two-thirds cottonseed meal and the remainder tankage, meat scrap, or fish meal is an excellent supplement to corn or other grain for pigs or brood sows that are on pasture. When no more of such a mixture is fed than is needed to balance the ration, the proportion of cottonseed meal is kept within limits that are safe, and the animal by-products make good the deficiencies in the quality of protein in the grains and in cottonseed meal. Unless the mixture contains at least one-half tankage or fish meal, a calcium supplement should be fed, since cottonseed meal is low in this mineral. For swine that are not on pasture, some legume hay should be added to a ration of grain, cottonseed meal, and tankage or fish meal, in order to provide an abundant supply of vitamins. This is especially necessary where grains other than yellow corn are fed.

The excellent results that are secured when cottonseed meal is fed in combination with tankage or fish meal are shown by many experiments, both with pigs in dry lot and with pigs on pasture. In 25 comparisons pigs gained 1.52 lbs. per head daily when fed a combination of cottonseed meal and tankage as the protein supplement to grain, in comparison with 1.44 lbs. for others fed tankage as the only supplement.[75] In these experiments 100 lbs. of cottonseed meal were equal in value to 65 lbs. corn plus 43 lbs. tankage. In 13 similar experiments in which a combination of cottonseed meal and fish meal has been compared with fish meal as the only supplement, the cottonseed meal has had a similarly high value.[76] A combination of half cottonseed meal and half soybean oil meal is usually fairly satisfactory.

Cottonseed meal is a satisfactory substitute for linseed meal in the trio supplemental mixture for pigs not on pasture, which consists of 50 lbs. tankage or meat scrap, 25 lbs. linseed meal and 25 lbs. chopped or ground legume hay.

However, in 10 experiments in which the cottonseed-meal trio mixture has been directly compared with the linseed-meal trio mixture for young pigs in dry lot, the results have been slightly better on the latter.[77]

While low-gossypol cottonseed meal or that which has been treated with ferrous sulfate to destroy the free gossypol has not been satisfactory as the only protein supplement for growing and fattening pigs, in Florida experiments it produced nearly as good results as did soybean oil meal, when used as the supplement for sows on pasture.[78] For swine, even low-gossypol cottonseed meal should be fed in combination with meat scrap, tankage, fish meal, or soybean oil meal, which have more lysine.

819. Cottonseed meal for poultry.—In the southern states, where cottonseed meal is frequently the cheapest protein-rich feed, it is often used in poultry rations. Extensive experiments have therefore been conducted to determine the extent to which cottonseed meal can be used satisfactorily for poultry.[79]

Ordinary cottonseed meal can replace part of the meat scrap or other protein supplements of animal origin that would be needed to balance the ration. However, it should not be used as the chief protein supplement, because the quality of the protein is not high and also because of possible detrimental results.

If the ration of laying hens has more than about 5 per cent of ordinary cottonseed meal, the yolks of the eggs are apt to develop an olive green or brown color and the albumen a pinkish color on storage. Cottonseed meal processed so that it is very low in free gossypol can be fed in larger amounts to hens without injuring the storage quality of the eggs. Such cottonseed meal can be used satisfactorily as the chief protein supplement for chicks, in combination with some fish meal, meat scrap, dairy by-products, or soybean oil meal, and if sufficient vitamins and calcium are provided.

820. Cottonseed feed.—Cottonseed feed, which usually contains less than 36 per cent protein, is not only lower in protein than cottonseed meal, but it is also higher in fiber and lower in total digestible nutrients. This is because it contains an appreciable proportion of hulls. Cottonseed feed is sometimes sold for but a few dollars a ton less than the best grades of cottonseed meal. It is therefore important to note the fiber guarantee for any lot of cottonseed meal or cottonseed feed.

One can determine approximately the proportion of additional hulls in a sample of cottonseed feed by comparing its fiber guarantee with the average fiber figures shown in Appendix Table I for high-grade cottonseed meal and for cottonseed hulls. By appearance alone it is impossible to distinguish good cottonseed meal from finely ground cottonseed feed.

Cottonseed feed may be an entirely legitimate product, for it is sometimes impossible to separate thoroughly the hulls of certain kinds of cottonseed from the kernels. However, such feed should be bought at a price corresponding to its actual value. In a Pennsylvania test cottonseed meal was a much more economical supplement than cottonseed feed for fattening cattle, though the price of the cottonseed feed was 19 per cent less a ton.[80]

821. Whole-pressed cottonseed.—This by-product is made by pressing the whole cottonseed, including the hulls, in oil expellers. Since it contains all the hulls, it is much lower in protein and higher in fiber than cottonseed meal and has a correspondingly lower value. Generally, it is guaranteed to contain 28 per cent protein and has 22 to 25 per cent fiber. A safe basis of valuing this feed is to estimate from the guaranteed composition the amount of cottonseed meal and of hulls there are in each ton, and value each at the local price. Thus, a ton of whole-pressed cottonseed having 28 per cent protein will be about equal to 1,200 lbs. of 43 per cent protein cottonseed meal and 800 lbs. of cottonseed hulls.

Whole-pressed cottonseed may be fed to stock in the same manner as cottonseed meal or cake. In 4 Texas trials it was worth 73 per cent as much per ton as 41 per cent protein cottonseed cake for fattening cattle.[81]

822. Cottonseed.—Commonly but little cottonseed is fed to stock, but instead farmers sell the seed to the oil mills and buy cottonseed meal. This is both on account of the value of the oil and because cottonseed meal usually gives better results as a stock feed. However, when the price for cottonseed is unusually low in comparison with that of cottonseed meal, it is an economical feed. Animals fed too large amounts of cot-

tonseed may scour badly, on account of the large amount of oil. There is no advantage in grinding cottonseed for cattle, and it is difficult to grind it in some mills because of the high oil content.

Cottonseed supplies only about half as much digestible protein per pound as does 41 per cent protein cottonseed meal, but it has one-fourth more total digestible nutrients, because it is so rich in fat.

In trials with dairy cows it has required 171 to 206 lbs. of cottonseed to equal 100 lbs. of cottonseed meal.[82] In a Mississippi test whole cottonseed, fed in a dairy concentrate mixture, was slightly superior to a mixture of 4 parts ground corn and 3 parts cottonseed meal.[83] Because of the high fat content of cottonseed, the fat percentage of the milk was increased slightly. It is sometimes difficult to get cows to eat the seed, unless a more palatable feed, such as ground corn or wheat bran, is mixed with it. Cottonseed has an even more marked hardening effect than cottonseed meal on the character of butter.

For fattening cattle cottonseed is an economical substitute for part or all of the cottonseed meal in a ration when it is decidedly cheaper in price. In Texas and Arizona experiments it required 103 to 140 lbs. of cottonseed to equal 100 lbs. of cottonseed meal in value.[84]

In other Texas trials where cottonseed was fed as a substitute for one-third the ground milo grain in a ration for fattening cattle, the cottonseed was worth 48 per cent more a ton than milo.[85] Feeding as much as 6 lbs. a day to fattening cattle did not cause scours.

Though cottonseed is rarely fed to sheep, the results were satisfactory in Texas tests when 0.4 to 0.6 lb. cottonseed per head daily was fed to fattening lambs as the protein supplement, or as a substitute for part of the grain.[86] The results were poor on a ration of only cottonseed and cottonseed hulls.

Immature cottonseed, or bolly cottonseed, is much lower in protein and fat than mature seed. Its feeding value is correspondingly less.

823. Gin trash.—Gin trash, a by-product from cotton gins, is composed mostly of fragments of burs and stems, with small amounts of immature cottonseed, lint, leaf fragments, and dirt. In a Texas trial gin trash, fed with sorghum grain, alfalfa hay, and cottonseed meal, was fully equal to cottonseed hulls for fattening cattle.[87] In a Mississippi trial it was satisfactory for wintering beef steers when fed in addition to silage and 1 lb. cottonseed meal per head daily, but it did not give good results as the only roughage.[88]

824. Cottonseed hulls.—Cottonseed hulls are one of the important roughages in the South, especially for cattle, to which they are chiefly fed. They are also sometimes fed to sheep or work stock. Cottonseed hulls supply 43.7 per cent of total digestible nutrients, which is about as much as is furnished by late-cut grass hay or by oat straw. The hulls are very low in protein and practically none of it is digestible. The hulls are also low in calcium, are very low in phosphorus, and are lacking in carotene.

To correct their deficiencies, cottonseed hulls should be fed with protein-rich feeds and as only part of the roughage, along with good-quality legume hay or other forage that will supply the carotene and the minerals in which they are deficient. Unless they are fed with considerable legume hay, a calcium supplement should be used, such as ground limestone or oyster shells. Also, a phosphorus supplement should be added, unless sufficient of this mineral is furnished by a phosphorus-rich protein supplement, such as cottonseed meal.

When properly fed, cottonseed hulls are generally about equal in value to fair-quality grass hay and are worth more per ton than corn or sorghum stover, straw, or poor hay. The hulls are well liked by cattle, even when fed as the only roughage.

Cottonseed hulls are usually fuzzy, due to short lint which remains on the seed. Sometimes this lint is removed from the seed at the oilmills for paper making and other purposes, and the hulls from such seed are ground, being then called *cottonseed hull bran.* Though finely ground, the value of the product is not appreciably greater than that of ordinary hulls.

825. Cottonseed hulls for dairy cattle.—Because of their nutritive deficiencies, cottonseed hulls should not be fed to dairy cattle as the only roughage over long periods. They should be fed with

some well-cured hay (especially legume hay) or good silage in addition, or to cattle which are on good pasture a considerable part of the time. If cottonseed hulls are used as the chief roughage, a calcium supplement should be fed.

When cottonseed hulls were fed in Louisiana tests with silage and a concentrate mixture supplying plenty of protein and calcium, they were superior to late-cut Bermuda grass and carpet grass hay for dairy cows and nearly equal to good Bermuda grass hay.[89] In other experiments cottonseed hulls were worth somewhat less per ton than good corn stover, Bermuda grass hay, Johnson grass hay, Sudan grass hay or sorghum hay for dairy cows or heifers.[90]

When bulky concentrates, such as oats and wheat bran, are not available or are high in price, cottonseed hulls may be useful to increase the bulkiness of a mixture of heavy concentrates.

826. Cottonseed hulls for beef cattle.—Cottonseed hulls are used extensively for beef cattle in the South and are a satisfactory roughage if the ration provides sufficient protein, minerals, and carotene. Instead of being fed as the only roughage, cottonseed hulls had best be fed with silage or with well-cured hay, especially legume hay. Unless some legume hay is fed, a calcium supplement should be used.

When cottonseed hulls replaced part of the alfalfa hay in rations for fattening cattle, they were worth about two-thirds as much as the hay in Texas trials.[91] Adding the hulls to the ration helped prevent bloat. In New Mexico tests cottonseed hulls, fed with alfalfa hay, were not equal to ground hegari fodder for fattening cattle.[92] In other experiments cottonseed hulls have been worth somewhat less than prairie hay, Johnson grass hay, or peanut hay.[93]

In 9 Florida and Mississippi tests 100 lbs. of cottonseed hulls were equal to 273 lbs. of sorghum silage, but in 4 Georgia trials 100 lbs. of hulls were only worth as much as 126 lbs. of corn-and-sorghum silage.[94]

Years ago, cattle were commonly fattened in the South on nothing but cottonseed meal and cottonseed hulls. However, if this ration is continued for any long period, the results are often poor, because of the deficiencies that have been discussed earlier in this chapter. (**810–811**) Even during the usual fattening period, the results are considerably improved if well-cured hay or good silage is added to this ration to furnish carotene, and also a calcium supplement, unless legume hay is fed. When hay or silage is not available, even the calcium supplement alone is beneficial, though the cattle will be affected by the vitamin deficiency if the ration is continued too long.

If cattle have been on excellent pasture before being placed in the feed lot for fattening, they may do surprisingly well on a ration of only cottonseed meal and cottonseed hulls plus minerals. This is because they will then have a considerable store of vitamin A in their bodies. Cattle a year old or more will do much better than calves on cottonseed meal and hulls alone. In South Carolina experiments 700-lb. steers gained as rapidly for 100 to 150 days on cottonseed meal and hulls as on shelled corn and alfalfa or lespedeza hay and showed no evidences of nutritive deficiencies.[95]

827. Cottonseed hulls for sheep.—Cottonseed hulls are less useful for sheep than for cattle. In 3 New Mexico trials when cottonseed hulls replaced part of the alfalfa hay in a ration for fattening lambs, the gains were reduced decidedly and the hulls had a very low value.[96] In Kentucky trials lambs gained appreciably less when fed a mixture of corn, cottonseed meal, and cottonseed hulls, with a little alfalfa meal and molasses, than on a simple ration of alfalfa hay and corn.[97] Thus fed, the hulls were worth only about one-third as much as hay.

In the southern states fattening lambs are sometimes fed cottonseed hulls as the only or the chief roughage, with grain and cottonseed meal or with cottonseed meal as the sole concentrate. Such a ration produces much less rapid gains than grain and legume hay, and if

it is continued for more than about 60 days injury may result, due chiefly to the lack of carotene and of calcium.[98]

III. Flaxseed; Linseed Meal and Cake; Other Flax By-products

828. Flaxseed.—In this country flax (*Linum usitatissimum*) is grown almost entirely as a cash crop for the production of linseed oil from the seed. Our flax fiber is nearly all imported from countries where the cost of labor is lower, for much hand labor is required in the production and preparation of flax fiber of the best quality.

Most of our flaxseed is grown in the Dakotas and Minnesota. A smaller acreage is raised in Montana and Texas and under irrigation in California, with small amounts being grown elsewhere. During the past few years the acreage harvested in this country has ranged from 3,303,000 to 5,663,000 acres, with average yields per acre of 7.3 to 9.8 bushels, weighing 56 lbs. Some flaxseed is imported into the United States, especially from Argentina, and processed here for linseed oil.

But very little flaxseed is fed to livestock, because of its high value for linseed oil production. However, ground flaxseed is entirely satisfactory as a protein supplement in place of linseed meal. Though it contains only two-thirds as much protein as linseed meal, it is one of the richest of feeds in total digestible nutrients. On account of its high oil content (which averages 35.9 per cent), it supplies more than 100 lbs. total digestible nutrients per 100 lbs. (including digestible fat multiplied by 2.25).

In feeding experiments with fattening cattle, fattening lambs, and pigs ground flaxseed has usually been equal or slightly superior to linseed meal in feeding value.[99] If too much flaxseed is fed to pigs, soft pork may be produced. Ground flaxseed is sometimes used as an ingredient in calf meals.

It is of interest to note that the reserve food stored in flaxseed is largely oil and pentosans, no starch grains being found in well-matured seed. Very rarely flaxseed may contain a compound (a glucoside) which, when acted upon by an enzyme in the seeds, yields the poison, prussic acid. This enzyme is destroyed by the heat to which the ground flaxseed is ordinarily subjected in oil extraction. In making gruel or mash from untreated flaxseed, it is advisable to use boiling water and keep the mass hot an hour or two, to destroy any prussic-acid-forming enzyme in the seed.

829. Linseed meal or cake.—Linseed oil is now produced in this country by all three oil-milling methods—the hydraulic, or so-called "old process;" the expeller, or screw-press method; and the solvent process. (794) The linseed cake produced in the hydraulic process is commonly ground to form linseed meal, or is ground more coarsely to make nut-size or pea-size linseed cake. Sometimes solvent-process linseed meal is pelleted in various sizes.

In this book the term linseed meal will generally be used for both linseed meal and linseed cake. Linseed meal or cake is sometimes called merely *oil meal* or *oil cake*. These terms should therefore always mean the linseed product, unless another designation is used, as soybean oil meal, for example.

Linseed meal is one of the most popular protein supplements in this country. Its popularity is due not only to its richness in protein, but even more to its palatability and to its slightly laxative effect, which aids in keeping stock healthy. Also, it seems to have a conditioning effect on stock.

Linseed meal is excellent as the only protein supplement for dairy cattle, beef cattle, sheep, and horses. Because of its laxative nature, linseed meal is of especial value when little or no legume hay is fed and the roughage is of rather poor quality. Linseed meal is highly esteemed in fitting cattle for show or sale, for it aids in producing bloom and in making the hide mellow and the hair glossy.

For swine and poultry linseed meal should be used in combination with an-

other protein supplement which provides protein of better quality, such as meat scrap, tankage, fish meal, or dairy by-products. As is pointed out later, linseed meal has little usefulness in poultry feeding.

On account of its popularity, linseed meal is often a more expensive source of protein than some of the other protein supplements. It should then not be fed as the only protein supplement, but should be combined with the cheaper supplements and used for its particular laxative and conditioning effects.

Linseed meal made by the hydraulic or the expeller process from North American flaxseed usually has at least 34 per cent protein, and has 4 to 5 per cent of fat. Solvent-process linseed meal is generally guaranteed to have 36 per cent protein, but has an average of only 1.0 per cent fat. While it is higher than hydraulic or expeller linseed meal in digestible protein, it is appreciably lower in total digestible nutrients. Linseed meal made from Argentine flaxseed may not have over 30 to 31 per cent protein, as the flaxseed raised there is lower in protein.

Linseed meal or cake is sold primarily on the basis of its protein content, and the percentage of protein should be stated definitely in the trade name of the meal. For example, linseed meal guaranteed to contain 34 per cent protein is called "34-per cent-protein linseed meal." Separate averages are given in Appendix Table I for the various grades of linseed meal.

The protein of linseed meal does not effectively supplement the protein of corn or other grains for non-ruminants. In this respect it is of lower value than the protein in well-cooked soybean oil meal. (122–123) Linseed meal has a fair calcium content, averaging 0.37 per cent, and is rich in phosphorus, with an average of 0.86 per cent. Linseed meal does not supply carotene or vitamin D, but has a fair content of the B-complex vitamins.

830. Linseed meal for dairy cattle. —Linseed meal is one of the most popular dairy feeds, because of its richness in protein and particularly because of its palatability and its conditioning and slightly laxative effects. For these reasons, many dairymen include at least 5 to 10 per cent of linseed meal in the concentrate mixture they feed their cows, even when other feeds, such as cottonseed meal or gluten feed, are cheaper sources of protein. Linseed meal is especially valuable when there is no succulent feed in the ration and little or no legume hay. It is likewise widely used as part of the concentrate mixture for cows on official test and in preparing cows for freshening. Linseed meal is also excellent for dairy calves and heifers.

Experiments have shown that when linseed meal is fed with good-quality roughage, so that its conditioning effect is not needed, it is worth slightly less per ton than cottonseed meal as a source of protein, because it is lower in digestible protein.[100] On the other hand, with poor roughage linseed meal would be worth more per ton than cottonseed meal. Linseed meal tends to produce soft butter, and therefore improves rations that would otherwise produce a hard, tallowy product.

In 2 Ohio trials solvent-process linseed meal was about equal to expeller-process as the protein supplement for dairy cows.[101] The hair of the cows fed the solvent oil meal was as glossy as that of the cows fed the expeller oil meal, and in this and in a Wisconsin test there was no difference in the palatability of the concentrate mixtures containing the different oil meals.[102]

831. Linseed meal for beef cattle. —Throughout the northern states linseed meal and mixtures including linseed meal are widely used as protein supplements for beef cattle. Linseed meal is of particularly high value for fattening cattle, because it produces rapid gains and excellent finish. Cattle fed linseed meal usually have a trifle sleeker coats than those fed other common protein supplements. They therefore tend to sell for a slightly higher price on the large markets, though the actual value of their carcasses may be no greater. Because of this conditioning effect, linseed meal is

commonly included in concentrate mixtures for cattle that are being fitted for show or for sale. Linseed meal is also excellent for young stock or breeding cattle.

Although cottonseed meal is richer than linseed meal in protein, linseed meal usually has a decidedly higher value per ton when fed as the only protein supplement to fattening steers, if the cattle are sold on a discriminating market. In 42 experiments fattening cattle fed linseed meal as the only supplement gained an average of 2.29 lbs. per head daily, while those fed cottonseed meal averaged 2.20 lbs.[103] The cattle fed linseed meal also required slightly less feed per 100 lbs. gain. Considering only this factor, cottonseed meal would have been worth about 89 per cent as much as linseed meal in these trials.

However, in nearly all of the experiments the cattle that had been fed linseed meal sold for a slightly higher price, either because of better finish or a sleeker appearance. On the average, there was a difference of 16 cents per hundredweight in selling price in favor of the linseed-meal-fed cattle. Though this difference may seem small, it is of importance, because it applies to the entire weight of the cattle when they are marketed.

Primarily because of this difference in average selling price, the average net return per head over cost of feed was distinctly higher for the cattle fed linseed meal, even though the cost of the linseed meal was $4.09 per ton higher than that of the cottonseed meal.

Taking both the difference in selling price and the difference in amounts of feed required per 100 lbs. gain into consideration, in these experiments it would have been necessary to buy cottonseed meal at only 62 per cent of the price of linseed meal to make an equal net profit per head.

These experiments do not mean that cottonseed meal is not satisfactory as the only protein supplement for fattening cattle. However, they show that linseed meal produces slightly more rapid gains and appreciably better finish. When the cattle are sold on a discriminating market, the difference in selling price is sufficient to give a decidedly higher value per ton to linseed meal, because only a relatively small amount of supplement is needed to balance most rations.

In contrast to these results with fattening cattle, are Kansas experiments in which beef calves or yearlings were wintered on Atlas sorghum silage, or sorghum silage and prairie hay, supplemented with 1 lb. per head daily of linseed meal, cottonseed meal, or soybean oil meal.[104] The cattle made slightly better gains on cottonseed meal or soybean oil meal than on linseed meal, perhaps because 1 lb. a day of linseed meal did not supply as much protein as the same weight of the other supplements. When the other feeds in a ration are very laxative, cottonseed meal will also be superior to linseed meal, as has been mentioned previously. (814)

Solvent-process linseed meal is of only slightly lower value than expeller-process or hydraulic-process linseed meal for fattening cattle. In 5 experiments fattening cattle fed solvent-process linseed meal as the protein supplement gained an average of 2.08 lbs. a day, in comparison with 2.15 lbs. for others fed that made by the expeller or the hydraulic process.[105]

832. Combining cottonseed meal and linseed meal.—Some years ago, after the author and associates had compared cottonseed meal and linseed meal in experiments with fattening steers, it occurred to him that a mixture of one-half linseed meal and one-half cottonseed meal might be fully equal to linseed meal alone. Accordingly, experiments were conducted at the Wisconsin Station to study this question, and similar tests were carried on later at the Iowa and Kansas Stations.[106] In 9 trials the gains were fully as rapid on the combination of cottonseed meal and linseed meal as on linseed meal fed as the only supplement. Though the selling price averaged 13 cents per hundredweight higher on the latter ration, slightly less feed was required per 100 lbs. gain on the mixed supplement. Considering all factors, the

average value per ton of the cottonseed meal-linseed meal mixture was 97 per cent that of linseed meal.

These trials show that although under most conditions linseed meal is considerably superior to cottonseed meal as the only supplement for fattening cattle, a mixture of these two supplements is practically equal to linseed meal in value.

833. Linseed meal for sheep.—Linseed meal is deservedly a very popular protein supplement for fattening lambs and the breeding flock. Because of the excellent results secured with linseed meal, it may well be taken as the standard with which other supplements are compared.

As has been shown earlier in this chapter, when there is considerable legume hay in the ration, cottonseed meal is practically equal to linseed meal as a protein supplement for fattening lambs. (816) However, if the lambs are fed little or no legume roughage, linseed meal is superior.

In a Minnesota trial with fattening lambs there was no appreciable difference in the value of linseed meal made by the hydraulic, the expeller, or the solvent process, and in a Nebraska trial solvent and expeller linseed meals were of equal value.[107]

834. Linseed meal for horses and mules.—Linseed meal is an excellent protein supplement for horses and mules. It is especially useful, because of its laxative and tonic properties, for bringing into condition rundown horses with rough coats, and it gives bloom and finish in fitting horses for show or sale.

Not over 1 to 1.5 lbs. of linseed meal per head daily are needed to balance such a ration as corn and timothy hay. In an Iowa test a mixture of 1 part of linseed meal to 16 parts of corn and oats was very satisfactory for feeding with timothy hay to horses at hard work.[108] Too large a proportion of linseed meal is unduly laxative for hard-worked horses.

835. Linseed meal for swine.—Linseed meal is an excellent protein supplement for swine, when it is fed in combination with such animal by-products as tankage, fish meal, or skimmilk. For example, it produces excellent results when used in trio-type mixtures for pigs not on pasture, discussed in Chapter XXXIV. If used as the only protein supplement to corn or other grain in swine feeding, linseed meal is much less efficient than feeds that supply protein of better quality.

Linseed meal produces fairly satisfactory results when fed as the only protein supplement to growing and fattening pigs on good pasture, but the gains are less rapid than when a more efficient supplement is used. In 9 experiments 59-lb. pigs fed corn and linseed meal on alfalfa pasture or rape pasture gained 1.29 lbs. per head daily, while others fed corn and tankage gained 1.34 lbs.[109] When linseed meal was thus fed, it was worth about 55 per cent as much per ton as tankage.

Such a ration as corn and linseed meal is decidedly unsatisfactory for young pigs not on pasture, even if a calcium supplement is added to correct the lack of this mineral in both grain and linseed meal. For example, in 5 experiments pigs thus fed gained only 1.08 lbs. per head daily, while others fed corn and tankage gained 1.37 lbs.[110] In these trials 100 lbs. of linseed meal were worth only as much as 66 lbs. tankage minus 100 lbs. corn.

Even for well-grown pigs, linseed meal is not efficient when fed as the only protein supplement to corn or similar grain. Where no animal by-products, like tankage, fish meal, or dairy by-products, are available to feed with linseed meal and grain to pigs not on pasture, much better results will generally be secured if legume hay is added to the ration, even when the grain is yellow corn.[111] However, in the case of young pigs, the gains will be much less rapid and economical on a ration of corn, linseed meal, and alfalfa hay than when tankage or some other animal by-product is included in the ration.

Linseed meal is much more satisfactory as the only protein supplement to

barley or wheat than as a supplement to corn.[112]

836. Linseed meal for poultry.—In striking contrast to the excellence of linseed meal as a feed for cattle, sheep, and horses, it is not satisfactory when forming any important part of the rations for laying hens, chicks, or other poultry.[113] Linseed meal has not generally given good results in poultry feeding, even when combined with protein supplements of high quality, such as fish meal and milk by-products.

As little as 5 per cent of linseed meal has depressed the growth of chicks, when included in a ration otherwise satisfactory.[114] A ration containing 10 per cent of linseed meal caused the death of all the turkey poults to which it was fed.[115] The injurious effects of linseed meal can be prevented by soaking or autoclaving it, or by adding the vitamin pyridoxine to the ration.[116]

In view of the popularity and high value of linseed meal for feeding other classes of stock, it hardly seems wise to include it in poultry rations under any usual conditions.

837. Other flax by-products.—*Flaxseed screenings oil feed* is the ground product obtained after extraction of part of the oil from the smaller, imperfect flaxseed, weed seeds, and other material separated in cleaning flaxseed. The composition and value of this feed and also of flaxseed screenings vary widely.

Sometimes the screenings are not removed thoroughly from the flaxseed before it is processed, or screenings oil feed is added to the linseed meal. Such products must be sold as *linseed feed* and not as *linseed meal.* Since the feeding value of linseed feed will often be much less than that of linseed meal, one should read carefully the name on the tag or sack and note the guaranteed composition. Otherwise, he may pay a linseed-meal price for an inferior product. In certain cases such flaxseed by-products may contain so much bitter-tasting weed seeds that they are decidedly unpalatable to stock, and they may even produce an off-flavor in the milk of cows.

Flax plant by-product is that portion of the flax plant remaining after harvesting the seed and separation of the bast fibers and flax shives. It consists of the leaves, corticle tissues (bark and outer portions) of the stems, flax seed bolls, and immature seeds. According to the definition proposed by the Association of American Feed Control Officials, flax plant by-product should have at least 9 per cent protein and not over 35 per cent fiber.[4] However, even 35 per cent fiber is more than hay of fair quality usually contains.

This low-grade product is used in certain cheap formula feeds for cattle and sheep. It is a good absorbent for molasses.

IV. Various Legume Seeds and By-products

838. Peanuts.—Peanuts (*Arachis hypogaea*), called earth nuts in some countries, are an important crop in the southern states, being grown chiefly for human consumption as peanuts, peanut butter, or peanut oil. However, a considerable acreage is grown for hogging down, and also swine are often turned in to clean up any remaining nuts, after a crop of peanuts has been harvested. Unfortunately, as is discussed later, peanuts produce soft pork, though the pork is otherwise of good quality. When available, peanuts can also be used in limited amounts as a protein supplement for other classes of stock. "Peanut hay," which remains after the nuts are picked from the cured vines, has been discussed in Chapter XVI.

The acreage of peanuts grown for nuts in this country has been only about 1,450,000 acres during recent years, which is small in comparison with that of soybeans. The average yield of unshelled peanuts for a 10-year period was 792 lbs. per acre.

Whole peanuts, including the hulls, or shells, have an average of about 25 per cent of protein, which is of good quality. Though unhulled peanuts are high in fiber, they are very rich in total digestible nutrients, because of their fat content of 36 per cent. Like soybeans, peanuts are deficient in carotene and vitamin D, are low in calcium, and are not very rich in phosphorus. On exposure to the air, shelled peanuts soon become rancid.

Pigs fed whole harvested peanuts without other concentrates make very

satisfactory gains if supplied with salt and also a calcium supplement, such as ground limestone or oyster shell. For example, in 3 Florida experiments pigs thus fed gained 1.0 lb. per head daily on the average. They required only 201 lbs. of feed per 100 lbs. gain, because of the high content of total digestible nutrients and of net energy in the fat-rich peanuts.[117] If the salt or calcium supplement is omitted, the results are very poor. For young pigs raised in dry lot without any green feed, it would be advisable to supply well-cured legume hay in addition, to make sure of a sufficient vitamin supply.[118] The amounts of peanuts that can be fed without producing soft pork are stated in Chapter XXXIV.

In Alabama tests mature chickens would eat whole peanuts after they became used to them, without picking out the kernels.[119] For laying hens there was no advantage in grinding peanuts. When hens were fed considerable amounts of shelled peanuts, the results were poor, perhaps because of the high fat content.

SPANISH TYPE OF PEANUTS

Nearly one-third the acreage of peanuts in this country is commonly hogged down, though soft pork is produced by this method. (From U.S. Department of Agriculture.)

839. Hogging down peanuts.—In spite of the fact that hogging down peanuts produces soft pork, nearly one-third of the peanut acreage in this country is commonly thus harvested by turning pigs into the field to root out the nuts. This is because the method is a very cheap way of fattening pigs. Experiments have shown that it is very important to supply pigs hogging down peanuts with salt and a calcium supplement, or even a more complete mineral mixture.[120] Pigs may make a little more rapid gains when fed tankage or meat scrap in addition to the peanuts and peanut forage they get, but the gains may be fully as cheap without the animal-protein supplement.

Spanish peanuts are grown for hogging down in the early fall, as they sprout badly after maturity and must be hogged off in 4 to 6 weeks. Runner peanuts keep well in the ground until January or February. In trials during 7 years in Georgia, runner peanuts hogged down produced an average of 388 lbs. gain per acre, in comparison with 417 lbs. for corn and 462 lbs. for sweet potatoes, also hogged down.[121] However, much more labor is required to grow sweet potatoes than for peanuts. In Florida tests Spanish peanuts or runner peanuts did not so closely approach corn or sweet potatoes in the amount of pork produced per acre, as in the Georgia trials.[122]

Brood sows or very young pigs are not

commonly turned on a fresh peanut field, because large amounts of peanuts are said to be injurious to them. However, they can clean up the fields after peanuts have been dug for market, or after the fattening hogs have eaten most of a crop.

840. Peanut oil meal; peanut meal and hulls.—*Peanut oil meal* or *cake* is the by-product from the production of oil from peanuts which first have been well hulled or shelled. According to the definition of the Association of American Feed Control Officials, peanut oil meal should not have more than 7 per cent of fiber. If the fiber content is higher than this, it shows that the peanuts have not been well hulled, or that hulls have been added. Such a product should be sold as *peanut meal and hulls*, according to the official definition. However, much of the peanut oil meal on the market has considerably more than 7 per cent fiber.

Peanut oil meal of the 45 per cent protein grade, made from well-hulled peanuts, has an average of 46.6 per cent protein and only 5.5 per cent fiber. *Peanut meal and hulls* of the 41 per cent protein grade has 41.1 per cent protein, but has an average of 15.0 per cent fiber, and therefore supplies considerably less total digestible nutrients (73.3 per cent). Since the fiber content of feed sometimes sold as peanut oil meal varies widely, depending on the amount of hulls, one should carefully note the fiber guarantee before purchasing. A product having 15.0 per cent fiber will contain about 15 per cent more peanut hulls than peanut oil meal made from well-hulled peanuts. The value will be correspondingly less, because peanut hulls have little feeding value.

In compiling the analyses for Appendix Table I, feed called *peanut oil meal*, but having more than 7 per cent fiber, has been properly classed as *peanut meal and hulls.*

Peanut oil meal of 45 per cent protein grade has 42.4 per cent digestible protein and 84.5 per cent total digestible nutrients, thus being higher in both than is soybean oil meal. Peanut meal and hulls of the 41 per cent protein grade, expeller or hydraulic process, has 36.6 per cent digestible protein and 73.3 per cent total digestible nutrients, being slightly higher in both than cottonseed meal of the 41 per cent protein grade.

The quality of the protein of peanut oil meal is good, ranking close to that of soybean oil meal. However, it usually has less lysine than does soybean oil meal.

Peanut oil meal is low in calcium and has only about half as much phosphorus as cottonseed meal. It lacks carotene and vitamin D, like most other seed products. It is fair in content of thiamine, low in riboflavin, and especially rich in niacin and in pantothenic acid.

Peanut oil meal is one of the best protein supplements for livestock feeding. This is due not only to its richness in protein and total digestible nutrients, but also because it is well liked by stock and because the protein is of high quality. Peanut oil meal from well-hulled nuts generally equals or closely approaches soybean oil meal in value for dairy cattle, beef cattle, sheep, horses, and swine, and is of only slightly lower value for poultry.

Peanut oil meal tends to become rancid if stored too long, especially in warm, moist climates. In the South it should not be stored more than 2 to 3 months in cool weather and about 6 weeks in summer.

Since peanut hulls have but little feeding value, the worth of *peanut meal and hulls* will depend on the proportion of hulls contained. This can be estimated from the guaranteed fiber content.

841. Value of peanut oil meal for various classes of stock.—Peanut oil meal is most commonly fed to dairy cattle, and it is a very popular feed for milk cows in sections where it is available. In Georgia and Virginia experiments peanut oil meal was fully equal to soybean oil meal or cottonseed meal as the protein supplement for milk production.[123] It is somewhat laxative and when high in fat may be too laxative if it forms more than one-fourth of the concentrate mixture.

In several experiments with fattening cattle peanut oil meal has generally

been fully equal to cottonseed meal in value and equal or nearly equal to soybean oil meal.[124] On the other hand, in each of 3 Kansas experiments with beef calves and 3 with yearlings wintered on Atlas sorghum silage plus 1 lb. of protein supplement per head daily, peanut oil meal was slightly but distinctly inferior to cottonseed meal, soybean oil meal, or linseed meal.[125]

Peanut oil meal has been about equal to cottonseed meal or linseed meal as the protein supplement for fattening lambs.[126] It is also a very satisfactory protein supplement for horses or mules.

Peanut oil meal is an excellent protein supplement for swine.[127] If a calcium supplement is provided, it is satisfactory as the only protein supplement for pigs or brood sows on good pasture or for well-grown pigs in dry lot. For very young pigs in dry lot it is best to use peanut oil meal in combination with tankage, fish meal, or dairy by-products. A mixture of one-half peanut oil meal and one-half tankage, meat scrap, or fish meal produces fully as good results as an animal-protein supplement fed as the only supplement. Used as the only protein supplement for pigs fed corn or corn and alfalfa hay in 5 tests, 100 lbs. of peanut oil meal produced nearly as rapid gains as did tankage.[128] Each 100 lbs. of peanut oil meal replaced 51.6 lbs. tankage and 55.0 lbs. corn in feeding value. *Peanut meal and hulls* had a considerably lower value than this in 3 tests.[129]

Peanut oil meal is so palatable to pigs that they will eat much more of it than they need to balance their ration when self-fed corn and peanut meal separately, free-choice. This can be prevented by mixing ground corn and the peanut oil meal in the desired proportion. When peanut oil meal is low in price, a large proportion is sometimes included in the ration. However, feeding only 2 or 3 pounds of corn to each pound of peanut oil meal often produces soft pork. When fed in a larger proportion than needed to balance the ration, the additional peanut oil meal is only equal to corn in value per pound.

Peanut oil meal can be used in much the same manner as soybean oil meal for poultry.[130] Like soybean oil meal, it gives the best results when fed in combination with protein supplements of animal origin, such as meat scrap, fish meal, or milk by-products. It was concluded from North Carolina studies that at least one-half of the animal-protein supplements in mashes for laying hens can be replaced satisfactorily with peanut meal.[131] Peanut oil meal is not satisfactory as the only protein supplement, or when as much as 30 to 35 per cent is used in a chick ration to replace all the soybean oil meal.[132]

842. Peanut skins.—Peanut skins, also called peanut bran, are the by-product consisting of the thin red-brown covering of the kernels, together with more or less of the germs and broken bits of the kernels. Peanut skins have an average of 16.3 per cent protein, 23.9 per cent fat, and 11.8 per cent fiber. They are used chiefly in certain mixed feeds. Peanut skins were satisfactory as a substitute for wheat bran in Pennsylvania tests, when 20 per cent was included in the concentrate mixture for dairy cows.[133] As peanut skins are bitter in taste, they should be mixed with better-liked feeds.

843. Peanut hulls.—Peanut hulls, or shells, are a by-product at the factories making peanut butter, shelled peanuts, or peanut oil from shelled nuts. Commercial peanut hulls usually contain fragments of kernels and therefore have a little more protein and fat than the pure hulls.

Peanut hulls have an average of 6.7 per cent protein, considerably more than in cottonseed hulls, but they are extremely high in fiber, averaging 60.4 per cent. As a result, they supply only 18.8 per cent total digestible nutrients, which is far less than in straw.

In recent Texas and Virginia trials with beef cattle peanut hulls, ground very fine through a 1/8 to 3/8 inch screen, gave fair results when mixed with the concentrates, so they would be consumed readily.[134] In the Texas trials there were wide variations in the gains and finish of individual fattening cattle when ground peanut hulls formed any large part of the roughage.

844. Beans; cull beans.—Several varieties of beans (*Phaseolus*, spp.) are raised in this country for human food. These include ordinary field or navy beans, lima beans,

kidney beans, and the pinto beans and tepary beans of the Southwest. All of these varieties have the same general composition and feeding value. In amount of total protein and other nutrients beans closely resemble field peas. However, their feeding value is much lower. Beans are not very palatable to stock; their digestibility is not high when they are fed raw, especially to swine; and their protein is not of good quality.

The *cull beans* which are sorted out from the first-quality dry beans can be used satisfactorily for stock feeding, if attention is paid to their limitations. Such cull beans include not only discolored, shrunken, and broken beans, but also more or less waste, such as broken bits of stems, small stones, and dirt.

Ground cull beans can be fed to dairy cows as a substitute for other protein supplements, if they form not over about one-fifth of the concentrate mixture. Thus fed in Michigan experiments, they were worth about one-half as much as cottonseed meal per ton.[135] Unless the ground beans were mixed with palatable feeds, there was difficulty in getting the cows to clean up the feed. When beans are cooked, larger amounts can be fed to cows but this involves considerable expense.

For fattening cattle, the results were satisfactory when cull beans formed 16 per cent of the concentrate mixture, but poor when the grain mixture had 26 per cent of beans.[136]

Whole uncooked cull beans are suitable for fattening lambs when forming not more than 20 to 25 per cent of the concentrate mixture. A larger amount is apt to be unpalatable and to cause scours. The value of cull beans, fed to fattening lambs in such a mixture with barley and with alfalfa hay for roughage, has ranged from about 82 per cent of that of barley to fully equal to barley.[137]

In New York experiments there has been a decided benefit from adding 0.1 lb. linseed meal a day to corn and cull beans for fattening lambs.[138] In another New York experiment lambs made just as rapid and economical gains when cooked cull beans replaced all the corn or two-thirds the corn in a ration of corn, legume hay, corn silage, and 0.1 lb. linseed meal.[139] Lambs fed uncooked cull beans as the only concentrate have not made good gains and have required much feed per 100 lbs. gain.[140]

In Michigan tests cull beans were a satisfactory substitute for cottonseed meal as the protein supplement in rations for wintering breeding ewes.[141] Feeding too large a proportion of cull beans to breeding ewes may cause the "stiff lamb disease."

Cull beans give good results in swine feeding when thoroughly cooked and fed with grain, and preferably with an efficient protein supplement, such as tankage, meat scrap, or fish meal. In Michigan trials cooked cull beans (weighed before cooking) were worth 89 per cent as much as corn when 2 parts of beans and 1 part of corn were fed with tankage, alfalfa hay, and a mineral mixture.[142] In a California test cooked cull lima beans were about equal to ground barley in value when forming 15 to 30 per cent of a well-balanced ration.[143] Dry heating of the beans was not satisfactory, instead of boiling or steaming. In a Colorado test well-grown pigs gained as well on a ration of corn, cooked pinto beans, and alfalfa hay as others fed soybean oil meal in place of the beans.[144]

Beans are not commonly fed to poultry, but in a California test cull beans were used successfully to replace grain, when forming as much as 10 per cent of the ration for chicks.[145] For poultry it is best to cook beans and use them as part of a wet mash.

Mung beans (*Phaseolus aureus*) have recently increased rapidly in acreage in Oklahoma and surrounding districts, being grown as a late-sown cash crop to follow small grain. The green variety is grown mostly for seed production for human food, and especially for the preparation of bean sprouts. The cracked and cull beans cannot be used for sprouting and are used for stock feeding. Yellow mung beans are grown chiefly for forage. (493)

Extensive trials with mung beans at the Oklahoma Station show their value to be as follows: [146] When forming 30 per cent of the concentrate mixture for dairy cows, 100 lbs. of ground mung beans satisfactorily replaced 50 lbs. of corn and 50 lbs. of cottonseed meal. When substituted for cottonseed meal or cake as the protein supplement for fattening calves, the gains were as rapid and 100 lbs. of mung beans were equal in feeding value to 60 lbs. of cottonseed meal or cake plus 64 lbs. corn and 13 lbs. silage.

Mung beans were digested about as well by lambs as common protein supplements, but were not palatable when more than 0.35 lb. a day was fed. Ground mung beans could replace cottonseed meal in the trio supplemental mixture for pigs. For poultry, mung beans were satisfactory when forming as much as 30 per cent of the mash, provided it had proper protein, mineral, and vitamin

supplements. Cooking mung beans did not improve the value much for poultry. Mung beans could be used to replace two-thirds of the soybean oil meal and cottonseed meal in a ration for turkey poults.

845. Carob beans.—Carob beans (*Ceratonia siliqua*), also called algaroba or St. John's bread, are produced by a legume tree grown chiefly in Mediterranean districts. The seeds are imbedded in a thick, fleshy pod, rich in sugars, which forms about 89 per cent of the fruit.[147] The ground pods and seeds form *carob-bean meal,* which is used chiefly in certain mixed feeds, especially calf meals. It contains only 5.5 per cent protein, thus differing from most legume seeds.

In a California test crushed carob beans and pods were equal to ground barley as part of the ration for dairy calves.[148] In another California trial even 5 per cent of ground carob beans and pods was unsatisfactory in a ration for chicks.[149] In Hawaiian trials pigs made fair gains on a ration containing 70 per cent ground dehydrated carob beans and pods, and young turkeys over 8 weeks old made good gains when fed scratch grain and a mash having 25 per cent carob-bean meal.[150] Pigs did not do well on a ration containing 60 per cent chopped sun-dried carob beans.

846. Chick peas.—Chick peas (*Cicer arietinum*), also called gram or garbanzos, are grown for human food and also for stock in an extensive area from India to southern Europe and northern Africa, and in other warm regions. Chick peas resemble field peas in composition, but are slightly lower in protein and somewhat higher in fat.

847. Cowpeas.—The use of the cowpea (*Vigna sinensis*) for forage has already been discussed in Chapter XVI. The seeds of most varieties of cowpeas ripen unevenly, and therefore when the crop is grown for seed it is necessary to pick the pods by hand as they ripen, or else the plants are cut when about three-fourths of the pods are ripe, and before the first ones are shattered or damaged. For this reason cowpeas are used mostly for forage or for the production of seed for human food. However, some varieties of cowpeas can be combined for seed, with yields of 500 to 600 lbs. per acre.

In composition, cowpea seed is similar to field-pea seed. Cowpeas furnish protein of fair quality to supplement the cereal grains and may be used satisfactorily as a protein supplement in feeding cattle, sheep, horses, or swine. In 3 Oklahoma experiments fattening calves made about as good gains with 2.5 lbs. per head daily of ground cowpeas for the protein supplement as with 1.5 lbs. cottonseed cake.[151] The ground cowpeas were worth 59 per cent as much as cottonseed cake. For swine feeding, cowpeas had best be fed in combination with some other supplement that supplies better-quality protein.[152]

848. Guar.—Guar (*Cyamopsis psoraloides*), which has been mentioned previously in Chapter XVI, is a drouth-resistant legume that has been grown for centuries in India, for both human and animal food. The seed is a source of vegetable gum used as a thickener in salad dressings and other foods, and also used in industry.

In a trial by the United States Department of Agriculture rolled guar seed was a satisfactory protein supplement for steers, but in a Rhode Island test even 100 lbs. per ton of a by-product from producing vegetable gum from guar beans was unsatisfactory in a chick mash.[153]

849. Horse beans.—The horse bean (*Vicia faba*), or broad bean, is used in Europe to some extent for feeding stock, especially horses, as well as for human food. This legume grows fairly well in some parts of Canada, but has never proved a success in the United States, except in the central coast district of California. Horse bean seeds are similar in composition and feeding value to field peas. In Canadian trials ground horse beans were not satisfactory as the only protein supplement in a chick ration, but gave good results when combined with fish meal, meat meal, soybean oil meal, or linseed meal.[154]

850. Legume seed screenings.—*Alfalfa seed screenings* consist chiefly of the shriveled or light-weight alfalfa seeds removed in cleaning alfalfa seed, along with varying amounts of weed seeds, bits of alfalfa leaves and stems, etc. Screenings that contain but little low-grade material have an average of 31.1 per cent protein, 9.9 per cent fat, and 11.1 per cent fiber.

The screenings should be finely ground before feeding, to make them more digestible and to prevent infestation of the land with weeds. They are not very palatable to stock, but a limited amount can be satisfactorily included in a mixture of better-liked feeds. When forming one-quarter of the concentrate mixture for dairy cows in Idaho trials, each 100 lbs. of ground alfalfa-seed screenings replaced 57 lbs. of linseed meal and 42 lbs. of barley and wheat bran.[155]

Sweet-clover screenings are generally lower in protein and higher in fiber than alfalfa-seed screenings, and vary rather widely in composition. North Dakota tests show that the ground screenings may be used as part of the concentrates for stock in the same manner as alfalfa-seed screenings, a good grade being equal or superior to wheat bran in feeding value.[156]

Red- or alsike-clover-seed screenings resemble alfalfa-seed screenings in composition and may be used similarly.[157]

851. Lespedeza seed.—The annual lespedezas usually produce 300 to 500 lbs. of seed per acre and sometimes considerably more. The seed is as rich as linseed meal in protein and is a satisfactory protein supplement for stock feeding, when a surplus is available. It should be ground for cattle or swine, but need not be for sheep or poultry.

In a Missouri experiment with dairy cows ground lespedeza seed was equal to a mixture of cottonseed meal and soybean oil meal, when substituted for these feeds on an equal protein basis.[158] In Illinois and Missouri tests lespedeza seed was about equal to cottonseed meal or soybean oil meal for fattening lambs.[159] Ground lespedeza seed did not give quite as good results for fattening cattle in a Missouri trial, perhaps because there was difficulty in grinding it so as to crush all the seeds.[160]

Ground lespedeza seed is satisfactory as 10 to 20 per cent of a ration for chicks, replacing this much soybean oil meal.[161] In a Kentucky trial lespedeza seed and screenings containing 28 per cent protein was used successfully to replace as much as half the meat scrap in a ration for chicks or laying hens.[162]

852. Locust pods.—The pods of the honey locust (*Gleditsia triacanthos*) are high in sugar, like those of carob beans, and may be used similarly in stock feeding. In Alabama tests two varieties of thornless honey locust trees yielded at the rate of 1,266 to 2,798 lbs. of pods per acre when 5 years old.[163] Ground honey locust pods and seeds were a satisfactory substitute for oats in a concentrate mixture for dairy cows, and were very palatable.

853. Lupine seed.—The seed of most varieties of lupines (*Lupinus*, spp.) is poisonous to animals because of toxic alkaloids contained in it. However, varieties of yellow and blue sweet lupines have been developed which have little or no poisonous properties. In Florida and Georgia trials with fattening cattle ground sweet lupine seed was fairly satisfactory as a substitute for cottonseed meal, but was less palatable.[164] In another Florida test it did not give good results as the only protein supplement for chicks, but was fairly satisfactory when combined with soybean oil meal.[165] In English tests such sweet yellow lupine seed was satisfactory for dairy cows when as much as 5 lbs. were fed a day, for pigs when forming 10 per cent of the ration, and for poultry when forming 11 to 20 per cent of the feed.[166]

854. Mesquite pods and beans.—Mesquite (*Prosopsis juliflora*) and tornillo, a related species, are large leguminous shrubs or small trees common in certain sections of the southwestern states. Often these produce abundant crops of pods which are eaten by stock when they fall to the ground. The seeds are so small and hard that they largely escape digestion, unless the pods and seeds are ground finely. This is difficult, because of the high sugar content of the pods.

In New Mexico trials with sheep and pigs the value of mesquite and tornillo pods and beans varied widely, but on the average they were worth only about 40 per cent as much as grain.[167]

855. Peas; pea feed.—The acreage of *peas* (*Pisum sativum*, or *arvense*) raised in this country for the production of seed for stock feeding is very small, because the small grains generally yield a much greater weight of seed per acre. However, a considerable acreage of peas is raised for dry peas for human food and for seed peas in the northwestern states, especially in Washington and Idaho. The cull peas, consisting of split, small, or damaged peas, are used for livestock feeding, and may be practically equal to high-grade peas in feeding value. Cowpeas are often called peas in the South, but are a different legume.

As has been pointed out in Chapter XVI, peas are often grown with oats for hay, pasture, or silage. Also, field peas are raised sometimes in certain mountain valleys of the West, and the entire crop harvested by lambs or hogs which are grazed on it. Sometimes a combination of barley, oats, and field peas is grown for grain in the northern states.

Peas are raised chiefly in the northernmost states and other regions where the climate is cool, as they do not thrive unless the spring and summer temperatures are moderate. The average yield of peas in the United States for the 12-year period, 1943–1954 was 1,247 lbs. per acre.

Peas are relished by stock and are an excellent feed, when not too high in price. They have nearly as much protein as corn

gluten feed and furnish slightly more total digestible nutrients. Differing from soybeans, peas are low in fat, having an average of only 1.2 per cent. Peas are low in calcium and only fair in phosphorus, with a content of 0.50 per cent. The seed of green varieties equals yellow corn in carotene content (vitamin A value), and even yellow varieties have an appreciable amount. Peas lack vitamin D.

The protein of peas supplements that of the cereal grains to a considerable extent, but not so completely as does the protein of soybean oil meal. This is because peas are low in methionine, the essential sulfur-containing amino acid.[168] (**110**) However, peas give good results when fed as the only protein supplement to dairy cattle, beef cattle, sheep, or horses,[169] or to pigs on pasture. There is no appreciable difference in the value of green, yellow, or black (Austrian) peas.

Peas supply about as much digestible protein and total digestible nutrients as a mixture of one-half linseed meal and one-half barley, and are about equal to such a mixture in feeding value. Peas are excellent as part of the concentrate mixture in fitting sheep for show, because they produce firm flesh.[170] Peas should be ground for cattle and swine.

For pigs on pasture, peas give excellent results when used as the only supplement to grain, if calcium and phosphorus supplements are supplied.[171] For pigs in dry lot in Washington experiments, ground peas were also satisfactory as the only protein supplement to a mixture of ground barley and wheat, fed with alfalfa meal and a mineral mixture supplying calcium and phosphorus.[172] On the other hand, in similar Idaho trials peas did not produce as rapid gains, when fed as the supplement to ground wheat, as were obtained when peas were combined with a small portion of meat meal.[173] For pigs or for brood sows it is very important to include alfalfa or other legume hay in the ration, when peas are the supplement to grain.[174] In a Washington trial a ration of barley, wheat, cull peas, 20 per cent dehydrated alfalfa meal, and minerals was as satisfactory for brood sows as one containing fish meal in addition.[175]

In poultry feeding, peas can be used to replace about one-half the animal protein supplements which would be required to balance a ration, but should not be used in such a large proportion as is possible with soybean oil meal.[176] Peas and fish meal make an excellent combination.

When cull peas are considerably lower in price than grain, they are often used to replace part of the grain in rations for dairy cattle, fattening cattle and lambs, or swine. Thus fed, cull peas of a good grade are equal to barley. If ground peas formed more than 40 per cent of the concentrate mixture for fattening calves in a Washington trial, there was serious trouble from bloat when the roughage was sweet clover hay.[177] In other Washington tests pigs on pasture made very satisfactory and economical gains when fed only cull peas and a mineral mixture.[178]

Pea feed, sometimes called pea meal, is the by-product from the manufacture of split peas for human food. It consists chiefly of shrunken, broken, or otherwise damaged peas, together with the pea hulls (or bran) and meal made up of the germs and broken particles from the seed. Pea feed varies considerably in composition. Though it has an average of 23.7 per cent fiber, the fiber seems to be highly digestible, and the content of total digestible nutrients is as high as in pea seed. When fed to dairy cows as part of a suitable concentrate mixture, pea feed has been equal to a mixture of grain, wheat bran, and linseed meal that supplied a similar amount of protein.[179]

856. Velvet beans; velvet bean feed.—Velvet beans are grown chiefly for forage, as has been mentioned in Chapter XVI. When the velvet beans are gathered for feeding to stock, they are generally fed whole in the pod, or else the beans and pods are ground to form *ground velvet bean and pod,* also called *velvet bean feed.*

Velvet beans in the pod contain 18.1 per cent protein and 13.0 per cent fiber, thus being slightly higher in protein but also higher in fiber than wheat bran. They supply slightly less than one-half as much protein as the best grades of cottonseed meal, but furnish as much total digestible nutrients.

Though velvet beans in the pod or the ground beans and pods are not very palatable, they are satisfactory for dairy cows, beef cattle, or sheep when not forming too large a part of the ration. When too much is fed, they may be unduly laxative. The dry beans and pods are satisfactory for fattening cattle, and it does not pay to soak or grind them. However, for dairy cows the value is increased considerably by grinding. If this cannot be done, the beans and pods should be soaked for 24 hours.

With dairy cows the best results are secured when ground velvet beans and pods do not form more than 40 per cent of the concentrate mixture, the rest consisting of better-liked feeds. Thus fed, this feed, on the

average, has been about equal to wheat bran and has been worth about one-half as much as cottonseed meal.[180] Ground velvet bean meal (without the pods) has a somewhat greater value, as it is higher in protein and total digestible nutrients.[181]

Velvet beans in the pod have been satisfactory for fattening cattle, when used as a protein supplement or when fed as the entire concentrate, along with suitable roughage.[182] In the latter case the gains are usually somewhat less than on a combination of corn and cottonseed meal. In 4 Georgia experiments fattening cattle fed 5.2 lbs. a day of velvet beans in the pod, along with broken ear corn in the husk, threshed peanut hay, and minerals, gained slightly more than others fed 2.5 lbs. of cottonseed meal.[183] On the average, the velvet beans in the pod were worth fully as much per ton as cottonseed meal, as they also replaced some corn and hay.

Velvet beans are generally very unsatisfactory for swine (either brood sows or growing and fattening pigs) when forming any considerable part of the ration.[184] This has been the case, no matter whether the beans have been fed shelled, ground, or as ground velvet beans and pods. The velvet beans even cause severe vomiting and diarrhea.

The poor results are caused largely by a substance that is poisonous to swine, and also by the poor quality of the protein in the beans.[185] The toxicity is lessened by cooking and the beans are made more digestible, but this does not generally make them satisfactory. Pigs will not do well when following steers heavily fed on velvet beans, unless they get considerable other feed. When velvet beans do not form more than one-fourth the ration for swine and an efficient protein supplement like tankage or fish meal is included, fair results may be secured.[186] Even velvet bean pasture cannot be recommended for swine.

857. Vetch seed.—The seed from the vetches (*Vicia*, spp.) is similar to pea seed in composition, but vetch seed is sometimes poisonous to stock because of the presence of glucosides from which prussic acid may be formed. (**670**) Danger of poisoning can be avoided by soaking the seed for 24 hours or by steaming it thoroughly.

V. Other Seeds and By-products

858. Coconut oil meal or cake; coconuts.—Coconut oil meal or cake (also called copra oil meal) is the by-product from the production of oil from the dried meats of coconuts, the nuts of the coconut palm (*Cocos nucifera*). Coconut oil meal is made by all the methods—the hydraulic process, the expeller method, and the solvent process.

Coconut oil meal of the usual kind has somewhat less protein than corn gluten feed but more than wheat bran, the average being 21.4 per cent. The protein is of better quality than that in corn gluten feed, but is not of such high quality as that of soybean oil meal. Coconut meal should therefore not be fed as the only protein supplement to grain for swine not on pasture or for poultry. Some such supplement as meat scrap, tankage, or fish meal should be fed in addition.

Coconut meal of the usual kind has an average of 6.7 per cent fat and supplies a trifle more total digestible nutrients than does corn gluten feed. Some of the imported coconut oil meal, coming from small, inefficient oil mills is much higher in fat, averaging 12.0 per cent. Such high-fat coconut oil meal is apt to become rancid if stored too long in warm weather.

Coconut oil meal is fed mostly to dairy cows in this country and is an excellent dairy feed. In a Massachusetts test it was about equal to corn gluten feed, and in an Ohio trial it was fully equal to a mixture of one-half linseed or cottonseed meal and one-half grain.[187] In a Hawaiian experiment 28 per cent of coconut oil meal was a good substitute for part of the soybean oil meal and pineapple bran in a dairy concentrate mixture.[188]

Sometimes the feeding of old-process coconut oil meal may cause a very slight increase in the fat percentage of milk over a considerable period. (**1064**) A limited amount of coconut meal produces firm butter of excellent quality, but over 3 to 4 lbs. per head daily may make the butter too hard.

Coconut oil meal is also satisfactory as a protein supplement for fattening cattle or lambs.[189] For swine feeding, coconut oil meal may be used in place of such feeds as wheat middlings or linseed

meal.[190] Like these feeds, it does not generally produce good results when fed to young pigs not on pasture as the only supplement to grain.

Limited amounts of coconut oil meal can be included in poultry rations when sufficient protein of better quality is provided.[191] On the Pacific Coast 2.5 to 5.0 per cent of coconut meal is sometimes used in poultry mashes. In an English test 20 to 25 per cent of coconut meal was satisfactory as a substitute for wheat bran in the mash for laying hens.[192] On the other hand, in Philippine tests coconut oil meal did not give good results in rations for chicks and ducklings.[193]

If coconut oil meal is cheaper in price than grain it may be used as a substitute for part of the grain in feeding cattle, sheep, horses, or swine, being worth about as much per 100 lbs. as ground barley.[194] In Ohio tests coconut oil meal was worth more than corn when forming one-fourth of the ration for pigs, but it was worth only 88 per cent as much as corn when forming 40 per cent of the ration.[195]

Coconut oil meal of a good grade should be whitish or very light brown in color. Too high a temperature in the process of expressing the oil will result in a dark oil meal which has a lower value, because the digestibility is decreased considerably.

Coconut meal has a high capacity for absorbing molasses and is sometimes used for this purpose in mixed feeds. "Candied copra," a mixture of coconut oil meal with a considerable proportion of cane molasses, usually has only 11 to 14 per cent protein.

Coconuts were used successfully in Guam tests for feeding growing pigs and brood sows on pasture.[196] As the coconut meats contain 60 to 70 per cent fat, on the dry basis, the energy value is correspondingly high.

859. Acorns.—In some regions acorns, the nuts of various species of oak (*Quercus*, spp.), are of importance in swine feeding, the pigs usually being allowed to forage upon the scattered nuts. In an English test pigs made satisfactory gains when fed acorns and only a limited amount of concentrate mixture.[197] It required 174 lbs. of dried acorns to replace 100 lbs. of the concentrate mixture in feeding value.

Acorns may be used for other stock in limited amounts, but poisoning has been reported where stock ate damaged acorns or too large amounts.[198] Statements have been made that acorns tend to dry up cows, if a considerable amount is eaten. This may be due to the high content of tannin. In certain range districts of California, deformed calves, which are called "acorn calves," are sometimes produced by range cows. Investigations have shown that this trouble may occur where the cows eat no acorns, but are forced to live on weathered, mature range forage for a long time. (192)

In tests by the United States Department of Agriculture, the feeding to hens of rations containing 25 to 50 per cent of acorn meats, or 25 per cent of whole acorns or acorn hulls, produced eggs with olive-colored yolks, and the hatchability was decreased.[199]

860. Adlay, or Job's tears.—Adlay, or Job's tears (*Coix Lacryma-Jobi*), a relative of the common cereals, has been cultivated since ancient times in Asiatic countries. The seeds of hard-hulled varieties are used as beads, and soft-hulled varieties are used for food. In tests in Brazil the yields of adlay seed were promising, in comparison with the common cereals.[200] The whole seed was used satisfactorily in rations for chickens and hogs.

861. Almond hulls.—Almond hulls are a by-product of the almond industry. The hull of the almond (*Prunus amygdalus*) is comparable to the fleshy portion of the peach, which is a close relative. When the almonds ripen, the hulls usually crack and open. After being harvested the nuts are removed from the attached hulls by a machine.

Until recently, most of California's almond-hull production was burned or used for livestock bedding. California experiments show that the dried and ground hulls can be used as a substitute for part of the grain for feeding ruminants.[201] The dried hulls contained 18 to 31 per cent sugar and only 10 to 17 per cent fiber, with a total digestible nutrient content of 53 to 72 per cent. Hulls from varieties with thick, fleshy hulls have the greatest feeding value.

862. Babassu oil meal.—Babassu oil meal is produced from the hard-shelled seed of a Brazilian palm (*Orbignya speciosa*). It is similar in appearance and composition to coconut oil meal, averaging a trifle higher

in protein. It is palatable to stock and in a Danish trial was about equal to coconut meal and in a New Jersey trial to corn gluten feed for dairy cows.[202] Like palm-kernel oil meal, it seems to cause a slight increase in the fat percentage in milk. In a California test with chicks, babassu oil meal satisfactorily replaced part of the grain, when not forming more than 10 per cent of the ration.[203]

863. Castor beans.—Castor beans (*Ricinus communis*) and the oil meal from processing them for castor oil are very toxic to stock. Studies are being conducted to develop a practical method of treating the oil meal to make it safe for feeding.[204]

864. Cocoa meal; cocoa shells; cocoa pods.—In the manufacture of chocolate and cocoa from the beans of the cacao tree (*Theobroma cacao*), the beans are first roasted and the cocoa shells, which form about 12 per cent of the weight, are removed. The beans are then ground very finely, and a portion of the semi-liquid mass is pressed to remove part of the fat, which is called cocoa butter. The residue, after hardening and being ground, forms the cocoa that is used as a beverage. Chocolate is made by enriching the ground beans with a certain percentage of cocoa butter.

On account of the large demand for chocolate in confections and other food, more cocoa must often be produced than can be sold for human use. This may then be offered for sale as a stock feed under the name of *cocoa meal*. Cocoa meal has an exceedingly low feeding value. Still more important, when it forms any appreciable part of the ration it is definitely poisonous, because of the alkaloids (theobromine and caffeine) which it contains. These alkaloids have a cumulative effect on animals.

Extensive experiments have been conducted to find whether or not cocoa meal can be safely fed to stock.[205] These experiments have shown that it is injurious or even disastrous to pigs and poultry when forming as little as 7.5 to 10 per cent of the ration. A mixture containing 15 per cent was unpalatable to stock, caused scours in calves, and decreased the milk yield of cows. Cocoa meal also has a very low digestibility and tends to depress the digestibility of the other feeds in the ration. Solvent-process cocoa meal has somewhat less alkaloids, but in English tests it was disliked intensely by pigs, poultry, and sheep.

Because of these results, even when cocoa meal is seemingly cheap in price, it should not be fed to stock, except perhaps to adult cattle in very small amounts in times of great feed shortage. In Great Britain during World War II the use of cocoa meal in mixed feeds was permitted only in feeds for adult cattle and to the extent of 2.5 per cent of the mixed feed.

Cocoa shells consist of the hard outside coating of the cocoa bean. These shells, which are dark brown and brittle, are used in a few mixed feeds. Only 27 per cent of the crude protein in this material is digestible, on the average. The shells from sun-cured cocoa beans have a considerable content of vitamin D.

In tests at the Massachusetts Station cocoa shells were worth not more than half as much as corn meal.[206] Woodman of England advises that cocoa shells be fed only to mature cattle and in amounts no greater than 2 lbs. per head daily, because cocoa shells contain small amounts of the alkaloids which make cocoa meal dangerous.[207] He concludes that cocoa shells when thus fed have no higher feeding value per pound than a good roughage.

Cocoa pods resemble grass hay in protein and fiber content, but in Costa Rica trials their feeding value for dairy cows was higher than would be expected from the chemical composition.[208] When ground, dried cocoa pods replaced ground corn in the ration, the milk production was just as high. In view of the chemical composition of cocoa pods, further trials would be needed to conclude that they equal corn in feeding value.

865. Coffee bean pulp.—Coffee bean pulp, the fleshy covering of coffee beans (*Coffea arabica*), has mostly been a waste by-product in coffee-growing countries. Experiments in El Salvador show, however, that it is nearly as digestible as corn grain and can be substituted for corn in a dairy ration.[209] It is not palatable when fed alone, but is readily eaten when mixed with molasses.

866. Hemp-seed oil meal.—Hemp-seed oil meal is the by-product in producing oil from the seed of hemp (*Cannabis sativa*). It contains 31 per cent protein, but it is high in fiber and furnishes less total digestible nutrients than good legume hay. In California tests hemp-seed oil meal was not palatable to stock.[210] It should therefore be mixed with better-liked feeds.

German authorities state that hemp-seed oil meal may contain narcotic substances which have injurious effects on stock when any large amount is fed. They recommend that dairy cows not be fed more than 1.1

lbs. of hemp-seed oil meal per head daily; horses and beef cattle not more than 3 lbs. per head daily; and sheep not more than 0.25 lb. per head daily. Hemp-seed oil meal is satisfactory in poultry rations when forming 2.5 to 5 per cent of the mash.[211]

867. **Ivory nut meal.**—Ivory nuts, or vegetable ivory, the nuts of the ivory palm (*Phytelephas macrocarpa*), are manufactured into buttons and the residue is ground finely to form ivory-nut meal. This consists chiefly of mannan, one of the less common carbohydrates. In studies at the Massachusetts Station this material was found to be fairly digestible.[212] It supplies about as much total digestible nutrients as barley grain, but contains only 0.8 per cent digestible protein.

868. **Kapok oil meal.**—Kapok oil meal is the by-product from the manufacture of oil from the seed of the kapok tree (*Ceiba pentandra*). Kapok fiber adheres to the seed of this tree in a manner somewhat similar to that found in the cotton plant. Kapok oil meal was so unpalatable to sheep in a California trial that the digestibility of the feed could not be determined.[210] When used for pigs as one-third of the protein supplemental mixture, along with tankage and alfalfa hay, kapok oil meal gave satisfactory results in Oregon tests.[213] It tended to produce hard pork.

869. **Mustard-seed oil meal.**—Mustard-seed oil meal, the by-product in producing mustard oil from various species of mustard seed (*Brassica,* spp.), can be used as a partial substitute for other oil meals in stock feeding. In Kansas and Montana trials mustard-seed oil meal was a satisfactory substitute for cottonseed meal or soybean oil meal for young beef or dairy cattle.[214] In Kansas trials it gave good results when forming not over half the protein supplement for pigs.[215] In another test 9 per cent was satisfactory as a substitute for part of the meat meal in a chick starter.[216]

870. **Palm-kernel oil meal or cake.**—The usual kind of palm-kernel oil meal or cake is the by-product from the production of oil from the seed kernels of certain tropical oil palms (*Elaeis,* spp.). It varies considerably in composition, especially in fiber content. The usual grade has slightly more protein than does wheat bran and supplies somewhat more total digestible nutrients.

Opinions differ with reference to the palatability of palm-kernel oil meal or cake. Woodman states that in England it is considered rather unpalatable, especially the solvent-process oil cake.[217] It should therefore be mixed with well-liked feeds and stock should be accustomed to it gradually. Palm-kernel oil meal or cake has been used chiefly in Europe, where it is mostly fed to dairy cows. Solvent-process palm-kernel oil meal was about equal to wheat bran for dairy cows in a Kentucky test, when used as a partial substitute for it.[218] Old-process palm-kernel meal may cause a temporary increase in the fat content of the milk and perhaps a very slight increase over a longer period. (**1064**)

Palm-kernel oil meal tends to produce hard fat when fed to stock, and thus makes firm butter and pork of good quality. It is not very palatable to pigs and should not form more than about one-fifth of their ration. Palm-kernel meal was a satisfactory substitute for wheat middlings in an English trial with laying hens.[219]

Oil meal is also made from the seed of the corozo palms (*Orbignya cohune* and *Scheelea,* spp.). In experiments in Guatemala this oil meal was found to be very palatable to stock.[220] It gave good results as the chief protein supplement for pigs and was a satisfactory substitute in rations for chicks when furnishing not more than half the protein.

871. **Perilla oil meal.**—This is the by-product from the production of oil from the seed of perilla plants (*Perilla,* spp.), Chinese plants which are members of the mint family. It contains an average of 38.4 per cent protein, but is high in fiber, having 20.9 per cent. In digestion trials at the California Station perilla oil meal was palatable to sheep. The protein and fat were well digested, but the fiber and the nitrogen-free extract poorly digested, and the feed had only 62 per cent total digestible nutrients.[210]

872. **Poppy-seed oil meal.**—This oil meal, which rarely appears on American markets, is the by-product from the production of oil from the seed of the opium poppy (*Papaver somniferum*). It contains about 36 per cent protein. Since it has weak narcotic properties, because of the presence of opium alkaloids, it is not generally fed to young animals or to breeding stock. The amount for dairy cows should be limited to 2 or 3 lbs. per head daily, since a greater amount is said to decrease the fat percentage of the milk.

873. **Rape-seed oil meal.**—Rape-seed oil meal, or colza oil meal, is the by-product from the production of oil from various kinds of rape seed (*Brassica,* spp.). It contains an average of 33.5 per cent protein, 8.1 per cent fat, and 10.8 per cent fiber.

Experience in Germany, where it has long been used for stock, shows that it must be fed very carefully to avoid injurious results.

Rape-seed oil meal contains varying amounts of glucosides, from which mustard oils may be formed in the digestive tracts of animals under certain conditions. The mustard oils are irritating to the digestive system and produce serious results when present in appreciable amounts. Also, rape-seed oil meal tends to produce goiter, especially in poultry, if fed in too large amounts.[221] This goitrogenic effect can be avoided by adding potassium iodide to the ration or by extracting the rape-seed meal with hot water.

To avoid bad results, it is best to feed no more than 2 lbs. per head daily to cattle and corresponding amounts to other stock. Not over 10 per cent should be included in a ration for laying hens and not over 5 per cent for chicks.[222] Caution is especially necessary in feeding rape-seed oil meal to young animals or to those which are pregnant. However, rape-seed oil meal, fed at the rate of 0.5 lb. per head daily to pregnant ewes being wintered, equalled linseed meal in a Canadian trial.[223]

On account of its sharp, bitter taste, rape-seed oil meal is often not liked by stock, especially at first. It should therefore be mixed with better-liked feeds.

874. Rubber-seed meal.—This by-product (also called Para rubber meal) from the manufacture of oil from the seed of the Para rubber tree (*Hevea brasiliensis*) is occasionally found on the United States markets. Rubber-seed meal is a dry, rather powdery meal which is not very palatable when fed alone. It should therefore be mixed with well-liked feeds. In a Virginia trial cows were fed 5 lbs. per head daily of either rubber-seed meal or linseed meal, with alfalfa hay and corn silage.[224] The rubber-seed meal gave as good results as the linseed meal in this ration, which supplied somewhat more protein than was required by the cows. In tests in England it was fed satisfactorily to milk cows and fattening cattle, but a few sheep refused to eat it, even when mixed with other feeds.[225]

875. Safflower oil meal or cake.—Safflower (*Carthamus tinctorius*) has long been cultivated in India and Egypt as an oilseed crop and a source of a red dye obtained from the flowers. It has recently been grown to some extent as an oil-seed crop in some of the western states.

Safflower seed of improved varieties has 29 to 36 per cent of oil, but has 40 per cent or more of hulls, which have very little feeding value. It is difficult to remove the hulls completely in oil-milling, and much safflower-seed oil meal is made from unhulled seed. Such oil meal has only about 18 to 21 per cent protein and contains 30 per cent fiber or more, as much or more than in hay. By improved methods, oil meal can now be made that has as much as 40 per cent protein and less than 10 per cent fiber. Safflower-seed oil meal is rather low in the essential amino acids lysine and methionine.[226] For poultry or swine these lacks are made good by fish meal.

Experiments have shown that safflower-seed oil meal from well-hulled seed is about equal to linseed meal or soybean oil meal as a protein supplement for dairy cows, beef cattle, or sheep.[227] On the other hand, it will require about 200 lbs. of safflower-seed oil meal from unhulled seed to equal 100 lbs. of the high-protein oil meals. Safflower-seed oil meal is too high in fiber to be useful in rations for chicks, but that low in hulls is satisfactory as a substitute for soybean oil meal for laying hens.[228]

876. Sesame oil meal or cake.—This protein-rich oil meal or cake is the by-product in the production of oil from sesame seed (*Sesamum*, spp.) which has been long produced in the Orient. The seeds of most varieties of sesame, or benne, shatter badly as they ripen, necessitating hand harvesting. Recently, non-shattering varieties have been developed, which can be harvested with a grain combine. These are attracting interest in some of our states, especially in Texas.

Sesame oil meal contains about as much protein as cottonseed meal, averaging 43.3 per cent. It is also high in calcium and phosphorus. It is well-liked by stock, keeps well in storage, and is satisfactory for all classes of stock. If it forms too large a part of the ration, it produces soft pork and butter.

Sesame oil meal is rather low in lysine and therefore should not be used as the only protein supplement for poultry or swine, but should be combined with such a supplement as meat scrap, fish meal, or soybean oil meal, which are rich in lysine.[229] It is an excellent protein supplement for dairy cattle, beef cattle, or sheep, and also for poultry or swine when fed with a lysine-rich supplement.[230]

877. Screenings; weed seeds.—When wheat and the other small grains come from the threshing machine or combine harvester, they contain various amounts of screenings. These must be removed as completely as

possible before the grain is milled for human food. The screenings consist of small, broken, or shrunken kernels of grain, wild oats and wild buckwheat, smaller weed seeds, and more or less chaff and broken pieces of stem.

When farmers market wheat or other grain before first cleaning it thoroughly, they not only lose the feeding value of the screenings, but they also have to take a lower price for the grain. The increase in price will much more than cover the cost of cleaning the grain, and in addition the screenings will be saved for feeding on the farm.

The best grades of screenings, consisting chiefly of broken and shrunken kernels of grain, with wild oats and other palatable weed seeds, resemble oats in composition. Such screenings, when ground, may nearly equal grain in feeding value.[231] Light, chaffy screenings are much higher in fiber and consequently lower in value. Some poor-quality screenings resemble straw more than grain in composition and value.

If the screenings contain too large a proportion of "black seeds" consisting of mustard seed, lamb's quarters, and pig weed, the value is low. In case there is much mustard seed present, the screenings may be very unpalatable to stock. Screenings containing a large proportion of certain weed seeds may even cause an objectionable flavor in the meat of animals heavily fed on them.[232] Poisonous seeds, such as corn cockle, are rarely present in sufficient amounts in screenings to cause bad effects. Flax screenings are usually considerably higher in fat than wheat screenings, due to immature or broken flax seeds. However, they are also generally higher in fiber.

In Canada recleaned wheat screenings are classified in definite grades under the Grain Inspection Act. No. 1 screenings must not contain more than a total of 6 per cent of weed seeds and No. 2 screenings not over 10 per cent. Either grade must not contain a sufficient proportion of injurious weed seeds to harm stock. The material removed in recleaning screenings is sold as "refuse screenings."

Unless the weed seeds in screenings are killed by very fine grinding, many will pass through stock uninjured and be carried to the fields in the manure. Therefore, screenings should be finely ground, even for sheep.

Tests at the Massachusetts Station showed that screenings ground in a hammer mill with sharp knives and four-sixtyfourths inch screens had very few viable weed seeds.[233] If the screenings had an unusual number of smaller noxious weed seeds, it was necessary to use three-sixtyfourths inch screens.

According to the official definition of the Association of American Feed Control Officials, *grain screenings* should consist of 70 per cent or more of grain (light and broken), including wild buckwheat and wild oats, should have not more than 6.5 per cent ash, and should not contain more than 4 whole primary noxious weed seeds per pound and not more than 100 secondary noxious weed seeds per pound.[4] *Mixed screenings,* to be labeled as mixed screenings (grains, seeds, hulls, chaff), are screenings not conforming to this definition. They should not contain more than 27 per cent fiber. If they have more than 13 per cent ash, the words "sand" and "dirt" must be included in the list of ingredients. *Chaff and/or dust* is the other material separated from grains or seeds in the usual commercial cleaning processes. If it contains more than 15 per cent ash, the words "sand" and "dirt" must appear on the label.

Ground screenings of good quality can be used satisfactorily as one-fourth or somewhat more of the concentrate mixture for dairy cows, beef cattle, or swine. The best results are secured when screenings are fed with considerable legume hay. Screenings are fed extensively to fattening lambs, especially in the wheat-growing areas of the West. Often they are used as the only concentrate. At the start light-weight, chaffy screenings are fed, and when the lambs are safely on full feed, heavier screenings, richer in grain, are substituted. In a Canadian trial No. 1 ground recleaned feed screenings were a satisfactory substitute for one-third of the corn in a broiler ration.[234] A larger proportion of screenings reduced the gains and feed efficiency. Various proportions of screenings are used in certain of the lower-grade mixed feeds, especially those for dairy cows.

The composition and value of alfalfa-seed screenings and other legume-seed screenings have been discussed earlier in this chapter. (**850**)

Cheat seed (*Bromus secalinus*), or chess, which is a common weed in grain fields, resembles oats in composition. Ground cheat was about equal to ground barley for dairy cows in Maryland trials, when forming 30 per cent of the concentrate mixture.[235] It is of interest that cheat, grown as a crop, produced more pounds of seed per acre than oats.

In Montana tests dairy cows ate concentrate mixtures readily which contained 10 per cent of *wild mustard seed* or 8 per cent of *fanweed seed*.[236] The milk yield was as high as on a normal mixture and the flavor of the milk was not injured.

878. Sunflower seed; sunflower seed oil meal.—In some countries, as in Argentina and Russia, sunflowers are an important crop for oil production. Also, the hulled seeds are used for human food. Recently, considerable acreages of low-growing varieties of sunflowers have been grown in western Canada for oil processing, and there has been some interest in sunflowers for oil production in this country. The use of sunflowers for forage has been discussed in Chapter XIX.

Only a very small amount of sunflower seed is raised here for feed, because other crops produce much larger yields of feed per acre. A small amount of sunflower seed (usually not more than 1 or 2 per cent) is often included in commercial mixed scratch grains for poultry, because of the distinctive and attractive appearance of the seeds.

Sunflower-seed oil meal or cake, made from thoroughly-hulled seed is even higher than soybean oil meal in protein, but that made from unhulled seed has only 20 per cent protein, or even less. Sunflower-seed oil cake is well-liked by stock and keeps well in storage. It is popular in Europe for all classes of stock, especially dairy cows.[237] It is said to resemble linseed meal in its favorable effect. Because of the character of the oil it contains, hydraulic-process or expeller-process sunflower-seed meal or cake tends to produce soft pork, and it also makes the butter soft, if fed in large amounts to dairy cows.

Sunflower-seed oil meal should not be used as the only protein supplement for poultry or swine, because the protein is rather low in lysine.[238] Over-heated sunflower-seed oil meal is especially deficient in lysine, which is destroyed by undue heat. Sunflower-seed oil meal should be combined with such a supplement as meat scrap or fish meal, which are rich in lysine. In swine or poultry rations it can partially replace soybean oil meal.

In Florida experiments sunflower-seed oil meal was fully equal to cottonseed meal as the protein supplement for fattening steers, but was decidedly inferior to soybean oil meal or peanut oil meal as the only protein supplement to corn and alfalfa meal for pigs.[239] In an Illinois test a combination of sunflower-seed oil meal, soybean oil meal, and alfalfa meal, was a good supplement to corn for pigs.[240]

QUESTIONS

1. Discuss the composition and nutritive value of soybeans.
2. For what classes of stock does cooking greatly increase the value of soybeans?
3. Describe the three oil-milling methods.
4. Why is soybean oil meal a popular feed?
5. What is soybean mill feed?
6. Discuss the use of soybeans for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry.
7. Compare the value of soybean oil meal and soybeans for each of the above classes of stock.
8. Discuss the composition and nutritive value of cottonseed meal. To what classes of stock should cottonseed meal be fed only in strictly limited amounts? Why?
9. Compare the value of cottonseed meal and of soybean oil meal or linseed meal for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry.
10. If the following are important in your district, discuss the composition and value: (a) Cottonseed feed; (b) whole-pressed cottonseed; (c) cottonseed.
11. Discuss the composition of cottonseed hulls and their value for: (a) Dairy cattle, (b) beef cattle, (c) sheep.
12. Why is not flaxseed commonly used as a feed?
13. Discuss the composition and nutritive value of linseed meal.
14. What is the value of linseed meal in comparison with other protein supplements for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry?
15. How are peanuts used for stock feeding?
16. Discuss the composition and value of: (a) Peanut oil meal; (b) unhulled peanut oil feed; (c) peanut skins; (d) peanut hulls.
17. Discuss the composition and use of any of the following that are of importance in your district: (a) Cull beans; (b) cowpeas; (c) lespedeza seed; (d) peas; (e) pea feed; (f) velvet beans.
18. Compare the composition and feeding

value of coconut oil meal and corn gluten feed.

19. Discuss the composition and use of any of the following that are fed to livestock in your section: (a) Acorns; (b) babassu oil meal; (c) palm-kernel oil meal; (d) rape-seed oil meal; (e) safflower oil meal; (f) sesame oil meal; (g) screenings; (h) sunflower seed; (i) sunflower seed oil meal.

REFERENCES

1. Shaw, Moore, and Sykes, Md. and U.S.D.A., Jour. Dairy Sci., 34, 1951, pp. 176–180; Elmore and Shaw, Md., Jour. Dairy Sci., 37, 1954, pp. 1269–1272.
2. See the review in Borchers et al., Nebr. Res. Bul. 152; see also: Hayward, Steenbock, and Bohstedt, Wis., Jour. Nutr., 11, 1936, pp. 219–234; 12, 1936, pp. 275–283.
3. Bird et al., Jour. Assoc. Offic. Agr. Chem., May, 1947; Balloun, Johnson, and Arnold, Iowa, Poultry Sci., 32, 1953, pp. 517–527; Liener and Hill, Minn., Jour. Nutr., 49, 1953, pp. 609–620.
4. Assoc. of Amer. Feed Control Officials, Official Publication, 1956.
5. Hackleman et al., Ill. Bul. 310; Fairchild and Wilbur, Ind. Bul. 289; McCandlish, Weaver, and Linde, Iowa Bul. 204; Fitch, Kan. Rpts. 1924–26, 1926–28; Schaefer, Minn. Bul. 239; Hayden and Perkins, Ohio Bimo. Bul. 121; Olson, S.D. Bul. 215.
6. Brooks, Mass. (Hatch) Rpt. 1894; Moore and Cowsert, Miss. Bul. 235; Cook, N.J. Rpt. 1913; Price, Tenn. Bul. 80.
7. Hilton, Wilbur, and Hauge, Ind., Jour. Dairy Sci., 15, 1932, pp. 277–281.
8. Cannon, Williams, and Espe, Iowa Farm Sci. Reporter, Jan., 1942; Williams, Cannon, and Espe, Jour. Dairy Sci., 19, 1936, p. 459; 22, 1939, pp. 442–443.
9. Wilbur, Hilton, and Epple, Ind. Rpts. 1936, 1937, 1940; Wilbur, Hilton, Epple, and Bratton, Ind. Rpt. 1939.
10. Wilbur, Hilton, and Hauge, Ind., Jour. Dairy Sci., 18, 1935, pp. 661–665; Hilton, Hauge, and Wilbur, Ind., Jour. Dairy Sci., 18, 1935, pp. 795–800.
11. Monroe, Hibbs, and Washburn, Ohio Farm and Home Res. 271.
12. Overman and Garrett, Ill., Jour. Agr. Res., 45, 1932, pp. 51–58; Ind. Rpt. 1932; Frye, Cannon, and Bird, Iowa, Jour. Dairy Sci., 33, 1950, pp. 205–215; Otis, Kan. Bul. 125; LaMaster and Elting, S.C. Rpt. 1929; Olson, S.D. Rpt. 1926.
13. Henke, Hawaii Bul. 95; Nevins, Ill. Rpt. 1924; Fairchild and Wilbur, Ind. Bul. 289; McCandlish, Iowa, Jour. Dairy Sci., 5, 1922, pp. 27–38; Moore and Cowsert, Miss. Bul. 235; Hayden and Perkins, Ohio Bimo. Bul. 121; Perkins, Bachtell, and Weaver, Ohio Bul. 516; Holdaway, Ellett, and Harris, Va. Tech. Bul. 28.
14. Rusk, Ill. Cir. 369; Skinner and King, Ind. Buls. 281, 291, 314, 330, 380, 428; King, Ind. Bul. 500; Evvard, Culbertson, et al., Iowa, mimeo. rpts.; Hodgson and Peters, Minn., mimeo. rpt.; Hinman, Morrison, Miller, Hobbs, and Wanderstock, N.Y., mimeo. rpt.; Bohstedt, Ohio Bimo. Buls. 105–106; Gerlaugh and Hackett, Ohio Bimo. Bul. 146.
15. Rusk, Ill. Cir. 369; Culbertson and Hammond, Iowa, mimeo. rpts.; Gerlaugh, Ohio Bimo. Buls. 140, 210.
16. Rusk, Ill. Cir. 369, Skinner and King, Ind. Buls. 330, 429; Gerlaugh, Ohio Bimo. Bul. 140.
17. Rusk, Ill. Cir. 369; Rusk and Snapp, Ill., mimeo. rpt.; Skinner and King, Ind. Buls. 281, 291, 314; King, Ind. Bul. 500; Culbertson, Shearer, Hammond, and Robinson, Iowa, mimeo. rpt.; Thalman, Nebr. Bul. 345; Marion, Fisher, and Jones, Tex. Prog. Rpt. 1599.
18. Brouse, Nebr. Bul. 357; see also: Baker, Nebr. Bul. 350.
19. Evvard, Culbertson, et al., Iowa, mimeo. rpts.; Culbertson et al., Iowa, mimeo. rpts.; Hodgson and Peters, Minn., mimeo. rpt.; Hinman, Morrison, Miller, Hobbs, and Wanderstock, N.Y., mimeo. rpt.
20. Rusk and Snapp, Ill. Rpts. 1936, 1937, and mimeo. rpts.; Culbertson, Shearer, Hammond, Robinson, and Beard, Iowa, mimeo. rpts.; Garrigus, Ky., Proc. 7th Dist. Feed Conf., 1952, pp. 12–16; Thalman, Nebr. Bul. 345; Baker, Nebr. Bul. 350; see also: Gallup, Briggs, and Hatfield, Okla., Jour. Anim. Sci., 9, 1950, pp. 194–200.
21. Morton, Osland, and Brandon, Colo. Press Bul. 80; Id. Buls. 205, 217; Kammlade and Mackey, Ill. Bul. 260; Harper, Ind., information to the author; Skinner, King and Starr, Ind. Buls. 192, 202, 221, 273, 282, 296; Cox, Kan. Rpts. 1938–40, 1940–42; Cox and Sloan, Kan. Rpt. 1940–42; Harris, Nebr. Rpt. 59; Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834; Bell, Ohio Buls. 373, 392.
22. Kammlade and Mackey, Ill. Bul. 260; Skinner and King, Ind. Buls. 273, 282, 296; Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834; Jordan, S.D. Bul. 442; see also: Miller and Morrison, N.Y., Jour. Agr. Res., 68, 1944, pp. 35–48.
23. Ill. Rpt. 1938–47.
24. Edmonds and Crawford, Ill. Cir. 369.
25. Culbertson, Helser, Thomas, Beard, and Hammond, Iowa Rpts. 1936, 1937, 1938, 1939, 1940 (Part 1), and mimeo. rpts.; Bull, Carroll, Olson, Hunt, and Longwell, Ill. Bul. 366; Vestal and Shrewsbury, Ind. Bul. 400; see also: Halverson, Hostetler, and Smith, N.C., Jour. Anim. Sci., 6, 1947, pp. 385–394.
26. Dvorachek, Sandhouse, and Hunt, Ark. Bul. 198; Bull et al., Ill. Bul. 366; Vestal, Ind., mimeo. rpt.; Bedenbaugh, Miss. Bul. 283; Robison, Ohio Bul. 452; Robison, Ohio Res. Bul. 699.
27. Vestal, Ind., mimeo. rpts.; Culbertson, Thomas, Hammond, and Beard, Iowa, mimeo. rpts.; Robison, Ohio Bul. 452.
28. Tomhave, Del. Bul. 170; Vestal, Ind., mimeo. rpt.; Culbertson, Thomas, Hammond, and Beard, Iowa, mimeo. rpts.; Bedenbaugh, Miss. Bul. 410; Robison, Ohio Bul. 452.
29. Vestal, Ind. Bul. 413; Ind. Rpts. 1937, 1938.
30. Vestal, Ind. Rpt. 1934 and mimeo. rpts.; Shrewsbury, Vestal, and Hauge, Ind., Jour. Agr. Res., 44, 1932, pp. 267–274; Robison, Ohio Bul. 452; Robison, Ohio Res. Bul. 699; Wilson, S.D. Rpt. 1933.
31. Brady et al., Mo. Bul. 556; see also: Mackintosh, Hall, and Vail, Kan. Rpt. 1948–50.
32. Vestal, Ind., mimeo. rpts.; Evvard, Culbertson, Hammond, and Wallace, Iowa, mimeo. rpt.; Culbertson, Thomas, Hammond, and Beard,

Iowa, mimeo. rpts.; Aubel, Kan. Cir. 207; Freeman, Mich. Quar. Bul., 24, 1942, No. 4; Robison, Ohio Bimo. Bul. 223 and mimeo. rpt.

33. Vestal, Ind., mimeo. rpt.; Aubel, Kan. Cir. 207; Freeman, Mich. Quar. Bul., 24, 1942, No. 2; Ferrin, Minn., mimeo. rpt.; Hanson, Nebr., mimeo. rpt.; Robison, Ohio Bimo. Bul. 207 and mimeo. rpt.; see also: Dyer and Krider, Ill., Jour. Anim. Sci., 9, 1950, pp. 176–179; Terrill, Nesheim, and Krider, Ill., Jour. Anim. Sci., 10, 1951, pp. 828–836; Robison, Ohio Res. Bul. 699.

34. Colo. Rpt. 1945; Roberts and Carrick, Ind. Rpt. 1938; Marvel, Carrick, Roberts, and Hauge, Ind., Poultry Sci., 23, 1944, pp. 294–297; Bird and Burkhardt, Md. Bul. A-27; Irwin and Kempster, Mo. Bul. 441; Kempster and Hall, Mo. Bul. 491; Heuser and Norris, N.Y. (Cornell) Bul. 810; Heuser, N.Y. Farm Res., 10, 1944, No. 4; Heuser, Norris, and McGinnis, N.Y., Poultry Sci., 25, 1946, p. 130; N.H. Bul. 351; Darrow, Patrick, and Morgan, S.C. Rpt. 1943; Sherwood and Couch, Tex. Bul. 588; Carver, Brant, and Evans, Wash. V. Cir. 15; Draper and Evans, Wash. V. Cir. 19; Berg, Bearse, and Miller, Wash., Poultry Sci., 24, 1945, pp. 122–125; Clark and Cunningham, West Va. Bul. 325; Christiansen, Halpin, and Hart, Wis., Poultry Sci., 19, 1940, pp. 55–60; Christiansen, Deobald, Halpin, and Hart, Wis., Poultry Sci., 18, 1939, pp. 481–485; 19, 1940, pp. 18–22; see also: Heuser, Feeding Poultry, 2nd Ed., 1955.

35. Bird and Burkhardt, Md. Bul. A-27; Marvel, Carrick, Roberts, and Hauge, Ind., Poultry Sci., 24, 1945, pp. 46–52; Sanford, Kan. Rpt. 1948–50; Nebr. Rpt. 1940; Wilgus, Norris, and Heuser, N.Y., Ind. and Eng. Chem., 28, 1936, p. 586; Bethke and Sweet, Ohio Bimo. Bul. 199; Robertson, Carver, and Cook, Wash. Bul. 388; Hayward, Halpin, Holmes, Bohstedt, and Hart, Wis., Poultry Sci., 16, 1937, p. 1.

36. Tomhave and Mumford, Del. Bul. 197; Carrick, Ind. Rpt. 1939; Kempster and Hall, Mo. Bul. 491; Nebr. Rpts., 1937, 1942, 1943; Norris and Heuser, N.Y. (Cornell) Rpt. 1936; Heuser, N.Y. Farm Res., 10, 1944, No. 4; Okla. Rpt. 1934–36.

37. Platt, N.J., Country Gentleman, July, 1946; Md. Rpt. 1944.

38. Wilgus, Gassner, and Patton, Colo., Poultry Sci., 19, 1940, p. 19; Colo. Rpt. 1945.

39. Ellis and Hodgson, U.S.D.A. Farmers' Bul. 1179.

40. Gallup, Briggs, and Hatfield, Okla., Jour. Anim. Sci., 9, 1950, pp. 194–200.

41. Reed, Huffman, and Addington, Mich., Jour. Dairy Sci., 11, 1928, pp. 488–515; Huffman and Moore, Mich., Jour. Dairy Sci., 12, 1929, pp. 410–418; 13, 1930, pp. 478–494; Halverson and Sherwood, N.C. Tech. Bul. 39; Kuhlman, Weaver, and Gallup, Okla. Rpts. 1930–32, 1932–34; Bechdel and Williams, Penn. Bul. 279; Bechdel, Williams, and Skaggs, Penn. Bul. 308; Copeland and Fraps, Tex. Bul. 473; Woodward, Shepherd, and Graves, U.S.D.A. Misc. Pubs. 130, 179; Hotis and Woodward, U.S.D.A. Tech. Bul. 473.

42. Kuhlman, Weaver, and Gallup, Okla. Rpts. 1930–32, 1932–34, 1936–38; Kuhlman, Weaver, and Nalbandow, Okla., Jour. Dairy Sci., 19, 1936, pp. 438–439.

43. Smith, Sherwood, Weldon, and Wood, N.C. Rpt. 1951.

44. Altschul, U.S.D.A., Poultry Sci., 33, 1954, pp. 180–185.

45. Sewell and Turney, Ala. Prog. Rpt. 26; Stephenson, Noland, and Camp, Ark. Bul. 523; Cunha, Shawyer, Wallace, and Pearson, Fla. Rpt. 1951; Barrick et al., N.C. Rpt. 1951.

46. Wallace, Combs, and Cunha, Fla. Rpt. 1952; Bridges, Dyer, and Burkhart, Ga., Jour. Anim. Sci., 11, 1952, pp. 474–479; Robison, Ohio Bul. 725; Chamberlain and Lidvall, Tenn. Farm and Home Sci., 10.

47. Robison, Ohio Bimo. Bul. 199, Ohio Bul. 695.

48. Fletcher and Barrentine, Miss., Jour. Anim. Sci., 8, 1949, p. 618.

49. Keith, Kuhlman, Weaver, and Gallup, Okla. Rpt. 1932–34; Miller and Wise, S.C., Jour. Dairy Sci., 27, 1944, pp. 275–296.

50. Eckles and Palmer, Mo. Res. Bul. 27; Keith, Kuhlman, Weaver, and Gallup, Okla. Rpts. 1930–32, 1932–34, 1934–36; Shields and Raitt, S.C. Rpt. 1917; Harrington and Adriance, Tex. Bul. 29.

51. Caldwell, Ind. Bul. 203.

52. Soule and Fain, Va. Bul. 156.

53. Kuhlman and Gallup, Okla., Jour. Anim. Sci., 1, 1942, p. 348.

54. Elting and LaMaster, S.C. Bul. 293; see also: Kuhlman, Weaver, and Gallup, Okla. Rpt. 1932–34.

55. Rusoff, Alford, and Hyde, La., Jour. Dairy Sci., 36, 1953, pp. 39–44.

56. Waugh, Wise, and Holden, N.C. Res. and Farming, 10, 1952, No. 4; Leighton, Anthony, Huff, and Rupel, Tex., Jour. Dairy Sci., 36, 1953, pp. 601–602.

57. Miss. Rpt. 1941.

58. Morton, Colo. Rpt. 1927; Morton and Osland, Colo. Press Bul. 78.

59. Pickett and Smith, Kan. Cir. 250; Smith, Cox, Good, and Mackintosh, Kan. Cirs. 273, 283; Miss. Rpt. 64; Pope et al., Okla. Misc. Pubs. MP-27, MP-31.

60. Pope et al., Okla. Bul. B-428; Marion, Fisher, and Jones, Tex. Prog. Rpt. 1599; see also: Smith, Good, Cox and Mackintosh, Kan. Cir. 273; Miss. Rpt. 62.

61. Edwards and Massey, Ga. Bul. 184; Weber, Kan., mimeo. rpt.; Cullison, Miss. Farm Res., 5, 1942, No. 8; Blizzard, Okla. Bul. 237 and mimeo. rpt.; Blizzard and Taylor, Okla., mimeo. rpts.

62. Stanley, Ariz. Bul. 137; Stanley and Walker, Ariz. Bul. 170; Scott and Stanley, Ariz., mimeo. rpts.; see also: Knox and Neale, New Mex. Bul. 262.

63. Stangel, Texas Tech. College, mimeo. rpt.

64. Craig and Marshall, Tex. Bul. 76.

65. Means, Miss. Farm Res., 7, 1944, No. 6; 8, 1945, No. 6: Tex. Bul. 724.

66. Skinner, Vestal, King, and Starr, Ind. Buls, 221, 256, 263; Paterson and Winchester, Kan. Cirs. 79, 96; Jordan and Peters, Minn. Bul. 306; Gramlich, Nebr. Bul. 173 and mimeo. rpts.; Alexander, Nebr., mimeo. rpts.; Holden, Nebr. Bul. 216; Morrison and Kleinheinz, Wis. Buls. 275, 323.

67. Skinner, Vestal, and King, Ind. Buls. 256, 263.

68. Briggs, Okla., Jour. Anim. Sci., 2, 1943, pp. 27–32.

69. Willey, Jones, and Lyerly, Tex. Bul. 733.

70. Briggs, Okla. Bul. B-252.

71. Cox, New Mex. Bul. 179; Neale, New Mex. Bul. 222 and Press Bul. 1009; Magee and

Darlow, Okla. Bul. 133; Quayle, Wyo. Bul. 191.
72. Kennedy, Robbins, and Kildee, Iowa Bul. 109; Templeton, Miss. Bul. 244; Godbey, S.C. Rpts. 1929, 1930; Ellis and Hodgson, U.S.D.A. Farmers' Bul. 1179.
73. Means, Miss. Rpt. 1932; Leveck, Miss., mimeo. rpt.; Williams, Jones, and Jones, Tex. Bul. 492.
74. Robison, Ohio Bul. 534; Hale, Tex. Bul. 410. Numerous references on the use of cottonseed meal in swine feeding are given in these bulletins.
75. Martin, Ark., mimeo. rpt.; Evvard, Culbertson, Hammond, and Bassett, Iowa, mimeo. rpt.; Aubel and Alexander, Kan. Cir. 187; Bray, Francioni, and Gregory, La. Bul. 228; Snyder, Nebr. Bul. 243; Loeffel, Nebr., mimeo. rpts.; Robison, Ohio Spec. Cirs. 26, 32; see also: Grimes, Sewell, and Cottier, Ala. Rpt. 1933; Maynard, Osland, and Brandon, Colo. Bul. 396; Massey, Ga. Cir. 118; Thompson, Okla. Rpts. 1930–32, 1932–34; Williams and Warren, Tex. Bul. 305; Hale, Texas Bul. 410.
76. Hostetler, N.C. Rpts. 1926, 1927, 1929, 1930; Hostetler and Foster, N.C. Sta., mimeo. rpts. and information to the author; Godbey and Starkey, S.C. Bul. 281.
77. Carroll and Smith, Ill. Rpt. 1927 and mimeo. rpt.; Vestal, Ind., mimeo. rpt.; Evvard, Culbertson, et al., Iowa, mimeo. rpt.; Aubel and Connell, Kan., mimeo. rpt.; Ferrin and Johnson, Minn., mimeo. rpt.; Robison, Ohio Bul. 488; Longwell, W.Va., information to the author.
78. Wallace, Cunha, and Combs, Fla. Bul. 566; Sewell, Keen, and Carmon, Ga., Jour. Anim. Sci., 14, 1955, p. 1222; Bedenbaugh, Miss. Bul. 410; Barrick et al., N.C., Jour. Anim. Sci., 9, 1950, p. 646; Robison, Ohio Bul. 705; Godbey and Starkey, S.C. Rpt. 64; Chamberlain and Lidvall, Tenn. Farm and Home Sci., 10.
79. Stephenson and Smith, Ark., Poultry Sci., 31, 1952, pp. 98–100; Grau et al., Cal., Jour. Agr. and Food Chem., 2, 1954, pp. 982–986; Driggers and Mehrhof, Fla. Rpt. 1953; Lewis and Sanford, Kan., Poultry Sci., 32, 1952, pp. 268–275; West, Miss., Poultry Sci., 34, 1955, pp. 547–553; Morgan and Willamon, S.C., Poultry Sci., 33, 1954, pp. 528–532; Patrick, Tenn., Poultry Sci., 32, 1953, pp. 942–944; Patrick, Tenn. Farm and Home Sci., 10; Couch, Chang, and Lyman, Tex., Poultry Sci., 34, 1955, pp. 178–183; Heywang, Bird, and Altschul, U.S.D.A., Poultry Sci., 34, 1955, pp. 81–90; Heywang, U.S.D.A., Agr. Res., 2, 1953, No. 3; see also: Heuser, Feeding Poultry, 2nd Ed., 1955; Ewing, Poultry Nutrition, 4th Ed., 1951.
80. Tomhave and Bentley, Penn. Bul. 183.
81. Willey, Jones, and Lyerly, Tex. Bul. 733.
82. Lush and Gelpi, La. Bul. 227; Moore, Miss. Bul. 60; Cunningham, N. Mex. Rpts. 1926, 1927.
83. Ramsey and Miles, Miss., Jour. Dairy Sci., 36, 1953, pp. 1308–1312.
84. Jones et al., Tex. Rpt. 1933; Tex. Bul. 724; Stanley and Walker, Ariz. Bul. 170.
85. Jones, Jones, and Bayles, Tex. Bul. 604; Jones, Dickson, Riggs, and Jones, Tex. Bul. 622.
86. Jones et al., Tex. Bul. 379; Tex. Rpts. 1933, 1944.
87. Jones, Logan, and Lyerly, Tex. Prog. Rpt. 1659.
88. Miss. Rpt. 66.
89. Lush, Staples, Fletcher, and Stewart, La. Bul. 238.
90. Moore, Miss. Rpt. 1902; Michels, N.C. Bul. 199; Conner, S.C. Bul. 66; Soule, Tex. Bul. 47; Copeland, Tex. Bul. 451.
91. Jones et al., Tex. Prog. Rpts. 1151, 1194, 1266; Tex. Bul. 724.
92. Knox, N. Mex. Bul. 343.
93. Massey, Ga. Bul. 211; Blizzard, Okla. Bul. 237.
94. Shealy and Gratz, Fla. Bul. 320; Buchanan, Miss. Bul. 278; Means, Miss. Bul. 301; Massey, Ga. Bul. 211.
95. Godbey and Starkey, S.C. Rpts. 1937, 1938, 1944.
96. Neale and Koger, New Mex. Bul. 335.
97. Garrigus, Ky. Bul. 566; see also: Tillman et al., Okla. Misc. Pub. MP-43.
98. Garrigus, Ky. Bul. 566; Neale, N. Mex. Bul. 200; Jones and Dickson, Tex. Bul. 379.
99. Morton, Fairbanks, and Osland, Colo. Press Buls. 78, 79, 80; Robison and Thatcher, Ohio Sp. Cir. 17; Wilson and Wright, S.D. Bul. 293.
100. Waters and Hess, Penn. Rpt. 1895; Michels, N.C. Rpt. 1910; Hills, Vt. Rpt. 1907.
101. Pratt and Monroe, Ohio Res. Bul. 731.
102. Allen, Wis. Bul. 492.
103. Morton and Osland, Colo. Press Bul. 78; Hickman, Rinehart, and Johnson, Id. Bul. 209; Evvard, Iowa, Corn Belt Meat Prod. Assoc., 1913; Evvard, Culbertson, et al., Iowa, mimeo. rpts.; Culbertson and Hammond, Iowa, mimeo. rpts.; Culbertson, Shearer, Hammond, and Robinson, Iowa, mimeo. rpts.; McCampbell and Marston, Kan. Cir. 117; Anderson and Marston, Kan. Cir. 130 and mimeo. rpts.; Anderson, McCampbell, and Alexander, Kan. Cir. 152 and mimeo. rpts.; Weber and Connell, Kan. Rpt. 1932–34; Allison, Mo. Bul. 150; Smith, Nebr. Bul. 100; Gramlich and Thalman, Nebr., mimeo. rpts.; Gerlaugh, Ohio Bimo. Buls. 140, 205; Gerlaugh and Hackett, Ohio Bimo. Bul. 146; Tomhave and Bentley, Penn. Bul. 183; Wilson, S.D. Bul. 148; Wilson and Wright, S.D. Bul. 329; Morrison, Fuller, and Roche, Wis. Bul. 388 and mimeo. rpts.
104. McCampbell and Aicher, Kan., Annual Cattlemen's Round-up, 1938, 1939; Pickett and Smith, Kan. Cir. 250.
105. Colo., mimeo rpt.; Culbertson, Shearer, Hammond, and Robinson, Iowa Rpts. 1939, Part 1; 1941, Part 1; 1942, Part 1, and mimeo. rpts.; Thalman, Nebr. Bul. 345.
106. Morrison, Fuller, and Roche, Wis. Buls. 388, 396; Fuller and Roche, Wis. Bul. 405; Culbertson, Evvard, et al., Iowa, mimeo. rpt.; Culbertson and Hammond, Iowa, mimeo. rpt.; Weber and Connell, Kan. Rpt. 1932–34.
107. Jordan and Peters, Minn. Farm and Home Sci., 1, 1944, No. 3; Harris and Alexander, Nebr. Rpt. 63.
108. Kennedy, Robbins, and Kildee, Iowa Bul. 109; see also: McCampbell, Kan. Bul. 186.
109. Weber, Alexander, and Marston, Kan. Cir. 138, and mimeo. rpt.; Weaver, Mo., mimeo. rpt.; Robison, Ohio Bul. 349; Grimes, Penn. Bul. 168; Morrison, Bohstedt, and Fargo, Wis. Bul. 323.
110. Robison, Ohio Bul. 349 and information to the author; Morrison and Bohstedt, Wis., mimeo. rpt.; see also: Ferrin and Winches-

ter, Kan. Cir. 78; Snyder, Nebr. Bul. 243; Hackedorn and Sotola, Wash. Bul. 169.
111. Weber, Anderson, and Marston, Kan. Cir. 138; Gramlich, Nebr. Bul. 175; Robison, Ohio Bul. 349; Morrison and Bohstedt, Wis., unpublished data.
112. Crampton and Ashton, Macdonald College, Canada, Sci. Agr., 26, 1946, pp. 545–547.
113. See review in Ewing, Poultry Nutrition, 4th Ed., 1951, pp. 358–367.
114. Hammond, U.S.D.A., Poultry Sci., 23, 1944, p. 78.
115. Milby, Penquite, and Thompson, Okla. Cir. C-111.
116. Kratzer, Williams, Marshall, and Davis, Cal., Jour. Nutr., 52, 1954, pp. 555–563.
117. Kirk and Crown, Fla. Bul. 372.
118. Halverson, Hostetler, and Sherwood, N.C. Tech. Bul. 41.
119. Kirk and Cottier, Ala. Cir. 80.
120. McCormick, Warner, and Shealy, Fla. Rpts. 1943, 1944; Kirk, Gratz, and Whitehurst, Fla. Bul. 389; Pace and Glasscock, Fla. Rpts. 1943, 1944.
121. Ga. Coastal Plain Sta. Buls. 29, 30, 31, 32, 35, 36, 40; see also: Templeton, Ala. Bul. 154.
122. Kirk, Gratz, and Whitehurst, Fla. Bul. 389.
123. Edwards and Massey, Ga. Bul. 216; Holdaway, Ellett, and Harris, Va. Tech. Bul. 28; see also: Ewing, Ridgeway, and Doubt, Tex. Bul. 238; Woodward et al., U.S.D.A. Bul. 1272.
124. Shealy and Gratz, Fla. Bul. 320; Massey, Ga. Bul. 211; Ga. Coastal Plain Bul. 42; Jacob, Tenn. Rpt. 1936; Burns, Tex. Bul. 263; Jones, Dickson, Jones, and Marion, Tex. Bul. 685; McComas, Douglas, and Southwell, U.S.D.A. Tech. Bul. 831.
125. McCampbell and Aicher, Kan., Annual Cattlemen's Roundup, 1938, 1939.
126. Miller, Cal., Amer. Soc. Anim. Prod., Proc. 1931; Dunn and Evvard, Iowa Bul. 185; Cox and Connell, Kan. Rpt. 1934–36.
127. Salmon, Ala., mimeo. rpt.; Massey, Ga. Cir. 138; Ga. Coastal Plain Sta. Buls. 36, 40; Aubel, Kan. Cir. 207; Bray, La. Rpt. 1943; Hostetler and Foster, N.C. Rpts. 1936, 1937, 1938, 1942; Godbey and Durant, S.C. Bul. 234; Hankins and Ellis, U.S.D.A. Bul. 1047.
128. Dvorachek and Sandhouse, Ark. Cir. 45; Evvard, Iowa, mimeo. rpt.; Aubel, Kan. Cir. 207; Robison, Ohio Bul. 349; Burk, Tex. Bul. 201.
129. McCampbell, Kan. Cir. 78; Barnett and Goodell, Miss. Bul. 218; Burk, Tex. Bul. 201.
130. King and Cottier, Ala. Cir. 80; Mehrhof and Moore, Fla. Rpts. 1943, 1944, 1945; Sherwood and Couch, Tex. Bul. 588; Temperton and Dudley, Harper Adams Utility Poultry Jour., England, 25, 1939–40, pp. 285–287.
131. Dearstyne, Bollinger, and Brigman, N.C. Bul. 326.
132. Grau, Cal., Jour. Nutr., 32, 1946, pp. 303–311; Driggers and Mehrhof, Fla. Rpt. 1953.
133. Borland, Penn., information to the author.
134. Langley, Jones, and McCullough, Tex. Prog. Rpt. 1396; Williams, Smith, and Jones, Tex. Prog. Rpts. 1483; 1699; Kincaid and Thomas, Va. Rpt. 1950–53.
135. Reed and Burnett, Mich. Quar. Bul., 6, 1923, No. 2; 7, 1924, No. 1; Huffman and Baltzer, Mich. Exten. Bul. 73.
136. Hickman, Rinehart, and Johnson, Id. Bul. 209; Vinke and Pearson, Mont. Bul. 251.
137. Rinehart, Hickman, and Johnson, Id. Bul. 194; Quayle, Wyo. Bul. 191; Quayle and Paules, Wyo. Cir. 44; see also: Nebr. Rpt. 60.
138. Willman and Embry, N.Y. (Cornell) Rpt. 1949.
139. Willman et al., N.Y., mimeo. rpts.
140. Miller, Cal. Bul. 431 and mimeo. rpt.; Maynard, Morton, and Osland, Colo. Bul. 379; Wilson and Lantow, N. Mex. Bul. 155.
141. Blakeslee, Brown, and Wells, Mich. Quar. Bul., 24, 1941, No. 1.
142. Edwards and Brown, Mich. Quar. Bul., 11, 1928, No. 2; see also: Thompson and Voorhies, Cal. Bul. 342; Shaw and Anderson, Mich. Bul. 243; Wilson and Lantow, N. Mex. Bul. 155.
143. Hughes and Heitman, Cal. Bul. 709.
144. Connell, Colo. Farm Bul. 6, 1944, No. 4.
145. Cal. Rpt. 1936–38.
146. Ronning, Kuhlman, and Cave, Okla. Bul. B-403; Ross, Darlow, MacVicar, and Stephens, Okla. Bul. B-370; Thayer and Heller, Okla. Bul. B-336; Briggs and Hillier, Okla., Jour. Anim. Sci., 4, 1945, pp. 430–434; Ligon, Okla. Bul. 284; Thompson and Hillier, Okla. Rpt. 1940–42 and mimeo. rpt.; Milby, Okla. Acad. Sci. Proc., 25, 1945, pp. 50–53.
147. Condit, Jatta, and Albro, Cal. Bul. 309.
148. Woll and Voorhies, Cal. Bul. 271.
149. Kratzer and Williams, Cal., Poultry Sci., 30, 1951, pp. 148–150.
150. Henke, Hawaii Bul. 99; Draper, Hawaii Cir. 23.
151. Pope, Long, Darlow, and MacVicar, Okla. Bul. B-399.
152. Duggar, Ala. Bul. 82; Gray, Duggar, and Ridgeway, Ala. Bul. 147; Willson, Tenn. Bul. 114.
153. Smith and Smith, R. I. Agr., 1, 1955, No. 1; Feed Stuffs, June 25, 1955.
154. Brisson, Nekolaiczuk, and Maw, Canada, Sci. Agr., 30, 1950, pp. 384–391.
155. Atkeson, Warren, and Johnson, Id. Bul. 206.
156. Dice, N.D. Buls. 217, 233; Hopper, N.D. Bul. 256; Griswold, N.D. Bul. 274.
157. Richards, Ore. Bul. 370.
158. Herman and Ragsdale, Mo. Bul. 451.
159. Kammlade, Ill. Rpt. 1938–47; Trowbridge and Dyer, Mo. Bul. 490.
160. Trowbridge, Comfort, and Dyer, Mo. Bul. 490.
161. Ackerson, Borchers, and Mussehl, Nebr. Rpt. 64.
162. Ky. Rpt. 1936; see also: Irwin and Kempster, Mo. Bul. 462.
163. Atkins, Ala. Rpt. 1942.
164. Glasscock, Cunha, and Pearson, Fla. Rpts. 1949, 1950; Ga. Coastal Plain Bul. 49.
165. Mehrhof and Davis, Fla. Rpt. 1948.
166. Aldershaw, Jour. Min. Agr., Great Britain, 51, 1944, pp. 128–134.
167. Wilson and Lantow, New Mex. Bul. 155.
168. Schneider and Miller, Wash., Jour. Nutr., 52, 1954, pp. 581–590.
169. Rinehart, Hickman, and Johnson, Id. Bul. 194; Vinke and Pearson, Mont. Bul. 251; Heinemann, Ensminger, and Ham, Wash. Bul. 543; Schneider and Christian, Wash. Stas. Cir. 163.
170. Humphrey and Kleinheinz, Wis. Bul. 232.
171. Lehrer, Beeson, and Wilson, Id. Cir. 108; Warwick and Cunha, Wash. Bul. 500.
172. Cunha, Warwick, Ensminger, and Hart, Wash., Jour. Anim. Sci., 7, 1948, pp. 117–126.
173. Beeson and Hickman, Id. Cir. 105; Lehrer and Hodgson, Id. Cir. 107; Id. Bul. 269.
174. Nordby and Snyder, Id. Cir. 48; Nordby, Id. Cir. 50, Id. Buls. 129, 131, 133, 135, 149;

Vaughan, Joseph, and Vinke, Mont. Rpt. 1927; Corbin, Wash. Bul. 260.
175. Colby, Cunha, and Ensminger, Wash. Stas. Cir. 153.
176. Carver, Bohren, and Cook, Wash. Bul. 418; see also: Peterson, Bolin, Lampman, and Stamberg, Id. Bul. 264; Lampman, Peterson, and Wiese, Id. Bul. 270.
177. McDonald and Ensminger, Wash. Bul. 439; see also: Beeson and Hickman, Id. Cir. 106.
178. Warwick and Cunha, Wash. Bul. 500.
179. Atkeson, Warren, and Bolin, Id. Bul. 213; see also: Knott, Tretsven, and Hodgson, Wash. Bul. 287; Ensminger and Heinemann, Wash. Bul. 470.
180. Templeton, Ferguson, and Gibbens, Ala. Bul. 198; Jarnagin, Ga. State Col. of Agr. Bul. 159; Hooper, Ky. Cir. 23; Lindsey and Beals, Mass. Bul. 197; Moore, Miss. Rpt. 1922; see also: Hunt, Va. Bul. 225.
181. Woodward et al., U.S.D.A. Bul. 1272.
182. Templeton, Ferguson, and Gibbens, Ala. Buls. 192, 198, Cir. 40; Scott, Fla. Bul. 102; Ga. Rpts. 1928, 1930; Miss. Rpts. 1922, 1924; Starkey and Salmon, S.C. Bul. 214, Rpts. 1924, 1925; Greene and Semple, U.S.D.A. Bul. 1333.
183. McComas, Douglas, and Southwell, U.S.D.A. Tech. Bul. 831; Ga. Coastal Plain Sta. Bul. 42.
184. Templeton et al., Ala. Buls. 198, 213; Miller, Grimes, and Salmon, Ala. Rpts. 1924, 1925, 1926, 1927; Dvorachek, Ark. Cir. 45; Scott, Fla. Bul. 141; Edwards, Ga. Cir. 84, Rpts. 1928, 1929, 1930; Good and Mann, Ky. Cir. 20; Norton, Mich. Rpt. 1918; Barnett and Goodell, Miss. Bul. 218; S.C. Rpts. 1922, 1923, 1925.
185. Miller, Jour. Biol. Chem., 44, 1920, p. 481; Jones, Finks, and Waterman, Jour. Biol. Chem., 52, 1922, p. 209; Read and Sure, Jour. Agr. Res., 24, 1923, pp. 433–440.
186. Lindsey, Mass. Bul. 197; U.S.D.A., Bur. Anim. Indus. Rpt. 1919.
187. Lindsey, Mass. Bul. 155; Perkins, Bachtell, and Weaver, Ohio Bul. 497.
188. Henke, Iwanaga, and Morita, Hawaii Rpt. 1948–50.
189. Guilbert, Cal. Bul. 418; Cal. Rpt. 1919.
190. Hughes and Feldmiller, Cal. Exten. Cir. 15; Hays, Del. Bul. 124; Robison, Ohio Bul. 349; Fjeldsted and Potter, Ore. Bul. 165; Hackedorn and Sotola, Wash. Bul. 169.
191. Kistler and Margolf, Penn. Bul. 196.
192. Temperton and Dudley, Harper Adams Utility Poultry Jour., 26, 1941, pp. 213–214.
193. De Los Sontas, Philippine Agr., 34, 1951, p. 174; Lioanag, Philippine Agr., 34, 1951, p. 236.
194. Thompson and Voorhies, Cal. Bul. 335; Headley, Nev. Rpt. 1934; Edwards, Guam, Rpt. 1926.
195. Robison, Ohio Bul. 600.
196. Edwards, Guam, Rpt. 1926.
197. Braude and Foot, Jour. Min. Agr., Great Britain, 50, 1943, pp. 227–229.
198. Wagnon, Guilbert, and Hart, Cal. Bul. 663.
199. Olsen, U.S.D.A., Poultry Sci., 21, 1942, pp. 497–499.
200. Schaaffhausen, Brazil, Economic Botany, 5, 1952, pp. 216–227.
201. Weir, Cal. Agr., 5, 1951, No. 9.
202. Frederiksen, Meddelelse fra Forsogslaboratoriets Husdybrugsafdeling, Denmark, 1923, No. 1; Mather, N.J., Jour. Dairy Sci., 36, 1953, p. 580.
203. Cal. Rpt. 1936–38.
204. Borchers, Ackerson, and Mussehl, Nebr. Rpt. 62; Okla. Rpt. 1946–48; Okla. Farm Res. Flashes, Nov. 1952.
205. Ellenberger and Newlander, Vt. Bul. 243; Ellenberger and Aplin, Vt. Buls. 272, 284; Aplin, Vt. Bul. 271; Cal. Rpt. 1936–38; Robison, Ohio Bul. 607; Woodman, Jour. Min. Agr., Great Britain, 48, 1941, pp. 45–46; 50, 1943, p. 223; Braude, England, Vet. Jour., 99, 1943, pp. 302–307.
206. Lindsey and Smith, Mass. Bul. 158.
207. Woodman, Jour. Min. Agr., Great Britain, 50, 1943, p. 223.
208. DeAlba, Costa Rica, Turrialba, 4, 1954, pp. 29–34.
209. Jour. Am. Vet. Med. Assoc., 112, 1948, p. 156.
210. Folger, Cal. Bul. 604.
211. Ewing, Poultry Nutr., 4th Ed., 1951.
212. Beals and Lindsey, Jour. Agr. Res., 7, 1916, pp. 301–320.
213. Ore. Bul. 359.
214. Aubel, Kan. Cir. 287.
215. Pickett, Weber, and Smith, Kan. Cir. 250, 34th and 35th Feeders' Day Rpts.; Keyes, Proc. 1st Mont. Nutr. Conf., 1951.
216. Kondra and Hodgson, Poultry Sci., 28, 1949, p. 771.
217. Woodman, Jour. Min. Agr., Great Britain, 49, 1942, pp. 44–45; 50, 1943, pp. 416–418.
218. Hooper and Nutter, Ky. Cir. 23.
219. Temperton and Dudley, Harper Adams Utility Poultry Jour., 25, 1939–40, pp. 285–287.
220. Squibb et al., Guatemala, Jour. Anim. Sci., 8, 1949, p. 630; 10, 1951, pp. 545–550; Poultry Sci., 31, 1952, pp. 118–122.
221. Kratzer, Davis, Williams, and Marshall, Cal., Jour. Nutr., 53, 1954, pp. 407–417; Hammond, Nebr. Bul. 409; Dow and Allen, Canadian Jour. Agr. Sci., 34, 1954, pp. 607–612; see also: Bell and Williams, Canadian Jour. Agr. Sci., 33, 1953, pp. 201–208.
222. Witz, Carpenter, and Hayward, Poultry Sci., 29, 1950, p. 786.
223. Bell and Weir, Canada, Sci. Agr., 32, 1952, pp. 496–501; see also: Burkitt, Mont. Cir. 193.
224. Ellett, Holdaway, Eheart, and Lasting, Va. Tech. Bul. 41.
225. Spring and Day, Agr. Bul. of Federated Malay States, 6, No. 5, 1918.
226. Kratzer and Williams. Cal., Poultry Sci., 30, 1951, p. 417–421.
227. Harris and Alexander, Nebr. Bul. 402; Baker, Clawson, and Ervin, Nebr. North Platte Progress Rpts. 63, 65; Christensen, N.D. Bul. 286; Heinemann, Ensminger, and Ham, Wash. Bul. 543; Wyo. Rpt. 62; see also: Stanley, Fahnish, and Safley, Ariz., mimeo. rpt.
228. Grau and Zweigert, Cal. Agr., 7, 1953, No. 12.
229. Almquist and Grau, Cal., Poultry Sci., 23, 1944, p. 187; Patrick, Tenn., Poultry Sci., 32, 1953, pp. 744–745.
230. Miller, Cal. Rpt. 1931; Almquist and Grau, Cal., Poultry Sci., 23, 1944, pp. 341–343; Henke, Hawaii Bul. 95; Hale and Polton, Jour. Agr. Sci., 38, 1948, p. 437; Baskett et al., Worlds' Poultry Sci. Jour., 3, 1947, p. 162.
231. Selvig, Minn., Crookston Substa. Rpt. 1924; Linfield, Mont. Buls. 47, 59; Nebr. Rpt. 1936; Griswold, N.D. Bul. 274; Foster and Merrill, Utah Bul. 78; Dunsmore, Canada Dept. of Agr., Pamphlet 87.
232. Richardson and Dickson, Mont. Bul. 320.

233. Kuzmeski, Smith, Vengris, and McLaughlin, Mass. Bul. 467.
234. Biely, March, Inkin, and Eldy, Canada, Poultry Sci., 30, 1951, pp. 593–598.
235. Berry, Turk, and Moore, Md., Jour. Dairy Sci., 27, 1944, pp. 627–628.
236. Tretsven and Nelson, Mont. Bul. 435.
237. Mangold, Handb. Ernähr, und Stoffwechsels, Vol. I, pp. 471–472; Halnan, Jour. Min. Agr., Great Britain, 30, 1924, p. 1166.
238. Slinger, Hill, Gartley, and Branion, Canada, Poultry Sci., 28, 1949, pp. 534–540; Renner, Clandinin, Morrison, and Robblee, Canada, Jour. Nutr., 50, 1953, pp. 487–490; Morrison, Clandinin, and Robblee, Canada, Poultry Sci., 32, 1953, pp. 542–547.
239. Pearson, Wallace, and Hentges, Fla. Bul. 553.
240. Krider, Becker, Carroll, and Wallace, Ill., Jour. Anim. Sci., 6, 1947, pp. 401–408; Ill. Cir. 608.

CHAPTER XXIII

MISCELLANEOUS CONCENTRATES

I. Cow's Milk and Milk By-products

879. Nutritive value of milk.—Whole milk is nearly a perfect food for young mammals. The great nutritive merits of milk have been considered in detail in Chapter IX, as well as the deficiencies that develop when milk is fed to young animals as the only food for an unnaturally long time. (269) The effects of various factors upon the composition and nutritive value of milk are discussed in detail in Chapters X and XXV.

Dairy Calves Need Milk
It is difficult to raise thrifty dairy calves unless they get a good start on milk.

It is important to note that pasteurization does not decrease the value of whole milk or of skimmilk, buttermilk, or whey for feeding dairy calves or other farm animals.[1]

880. Whole milk.—Whole cow's milk is too valuable for human food to be fed to livestock under usual conditions, except in the case of young dairy calves until they become old enough to live on other feeds. The use of whole milk for this purpose is discussed fully in Chapter XXVII. It is not necessary to continue the feeding of whole milk to calves longer than 2 to 4 weeks, if a plentiful supply of skimmilk is available or if reconstituted skimmilk (made from dried skimmilk) or an efficient milk replacer is fed. When other methods are followed, whole milk should generally be fed for a longer period.

One should not hesitate to use whole milk when needed in rearing an orphan foal or lamb, and young stock being fitted for show can be forced ahead rapidly by its judicious use. Milk moderate in fat content gives better results with young calves or pigs than milk very high in fat. (269)

Whole milk has about 3 per cent or more of casein, 0.5 per cent albumin, and traces of other proteins. It contains from 4.8 to 5.0 per cent of milk sugar, which is shown in feeding stuff analyses as nitrogen-free extract. Milk sugar is only slightly sweet, is much less soluble than cane sugar, and has about the same feeding value as starch. When milk sours, some of the sugar is changed to lactic acid, which curdles the casein. This fermentation ceases when about 0.8 per cent of acid has developed, so that in sour milk usually most of the sugar is still unchanged.

It is shown in Chapter XXV that the percentage of fat varies widely, depending on individuality, breed of cow, and the portion of the milk drawn. The strippings sometimes contain 10 times as much fat as the first-drawn milk.

Whole milk contains both vitamin A and carotene. The relative proportions of these depend on the breed of cow, as is pointed out in Chapter XXV. (1043)

881. Skimmilk.—Because of the removal of most of the fat, skimmilk is slightly higher than whole milk in content of protein, milk sugar, and minerals.

Skimmilk from properly-adjusted centrifugal separators has only 0.03 to 0.10 per cent fat.

Because of the low fat content, skimmilk supplies but little vitamin A value, since nearly all the vitamin A and carotene in milk are contained in the fat. Skimmilk also furnishes considerably less energy than whole milk per 100 lbs. because of the removal of the energy-rich fat. Skimmilk is rich in riboflavin and is a good source of vitamin B_{12} and other B-complex vitamins.

In feeding skimmilk, it should be borne in mind that it is very high in protein, on the dry matter basis. Because of this, there is no need of having other protein supplements in the ration when sufficient skimmilk is used. Instead, to secure the maximum value from skimmilk, it should be fed with cereal grain or other concentrates low in protein.

Skimmilk is used chiefly for dairy calves, pigs, and poultry. When fed in suitable amounts to these classes of stock, it has a considerably higher value per 100 lbs. than an equal amount of nutrients in the feeds from other animal sources, such as tankage, meat scrap, or fish meal. Skimmilk and other dairy by-products have an especially high value for poultry, largely because of their richness in riboflavin. Since skimmilk lacks vitamin A, it is highly important that the ration include other feeds which furnish plenty of vitamin A value.

Full information on the use of skimmilk in raising dairy calves is given in Chapter XXVII. It is there shown that just as thrifty calves can be raised when they are changed entirely from whole milk to skimmilk by 3 to 6 weeks of age, as when whole milk is continued longer. The use of skimmilk for swine and poultry is discussed in later paragraphs. (884–887)

If more skimmilk is available than can be used for calves, pigs, and poultry, it may be fed to dairy cows and heifers. Only a few cows will drink skimmilk, but it may be poured on the concentrate mixture in a pail, and this mixture then fed on top of the silage. In Minnesota trials 8 lbs. of skimmilk replaced 1 lb. of linseed meal when dairy cows were thus fed 2 lbs. of skimmilk per pound of grain mixture, and the value of skimmilk for dairy heifers was similar.[2] Skimmilk did not have quite as great a value as this for dairy cows in tests by the United States Department of Agriculture.[3]

882. Importance of pasteurizing factory by-products.—Farmers should insist that skimmilk, buttermilk, or whey be thoroughly pasteurized or sterilized at the factory to kill all disease-producing bacteria, before they take it back to the farm for feeding. Otherwise, bovine tuberculosis, brucellosis, or other diseases may be widely spread from a diseased herd. The pasteurized product also keeps better and is less likely to cause scours. Pasteurization is likewise advantageous to the factories, for the milk cans may be more readily kept in good condition and the quality of the milk delivered at the factory will thus be improved.

883. Buttermilk.—Unless wash water from the churn has been added, buttermilk has practically the same composition as skimmilk, except that it usually contains 0.4 per cent or more of fat. Also, in buttermilk from sour cream a part of the sugar has been changed to lactic acid. Buttermilk of good quality is a satisfactory substitute for skimmilk in feeding calves, pigs, and poultry, undiluted buttermilk being worth about as much as skimmilk.

Since buttermilk often has a more laxative effect than skimmilk, calves should not be changed to it quite so early as in the case of skimmilk. Buttermilk that is allowed to ferment and putrefy in dirty tanks is a dangerous feed.

884. Skimmilk and buttermilk for swine.—Because of the richness in excellent-quality protein, either skimmilk or buttermilk is an ideal protein supplement for all swine. When either skimmilk or buttermilk is used as the supplement to grain for pigs, the gains will generally be slightly more rapid than when tankage or fish meal is used as the

only supplement. These feeds are of especially high value for young pigs before weaning and also for several weeks after weaning.

It must be borne in mind that skimmilk, buttermilk, and whey are all very low in vitamin A value and that they have practically no vitamin D. For all swine not on pasture, good legume hay should therefore be fed, if possible, in addition to grain and these dairy by-products. Legume hay is especially necessary when little or no yellow corn is fed, and also for young pigs during winter when they are not protected against rickets by abundant exposure to sunlight.

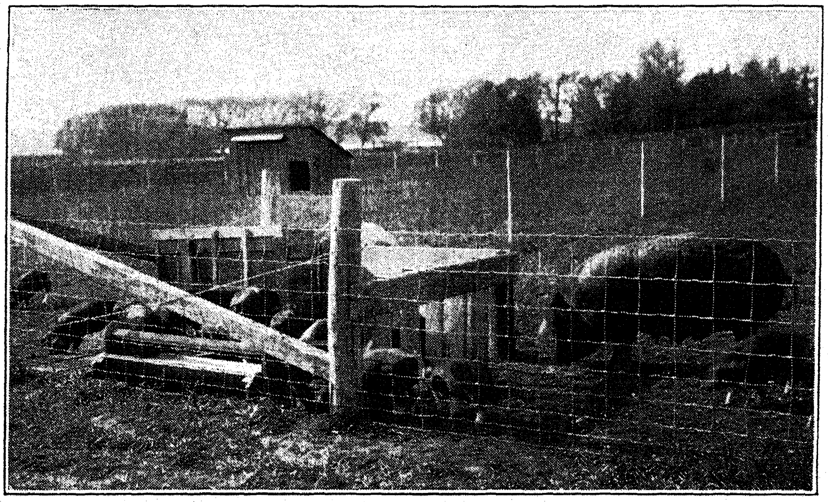
For pigs before and soon after weaning, skimmilk is best if fed fresh. If sour milk is used, it should always be fed sour, and not sweet at one feeding and sour at the next. To prevent the introduction of disease, dairy by-products should be pasteurized at the creamery or cheese factory before being returned to the farm.

Numerous experiments have shown that buttermilk which has not been diluted by the addition of churn washings has about the same value as skimmilk for swine.[4] Storage of buttermilk for a few days under sanitary conditions does not injure its value.[5]

The feeding of skimmilk, buttermilk, or whey to pigs helps to reduce infection with roundworms and other intestinal worms.[6]

885. Amount of skimmilk or buttermilk to feed swine.—Skimmilk and buttermilk are too rich in protein and also too watery to produce economical gains when fed alone. They should therefore always be fed with grain or other carbohydrate-rich concentrates. These dairy by-products have the greatest value when no more is used than will balance the ration. Much larger amounts can, however, be fed to swine when a surplus is available, after the dairy calves and poultry have had sufficient.

The additional skimmilk or buttermilk that may be used beyond the amount needed to balance the ration will, of course, be worth much less per pound than the portion that is actually needed as a protein supplement. This is be-



Skimmilk Is an Excellent Feed for Pigs and Calves

Rich in protein of the highest quality and high in calcium and phosphorus, skimmilk is a superior feed for young animals. These young pigs are being fed skimmilk and a suitable concentrate mixture inside the "creep," where the sows cannot enter. (From Wisconsin Station.)

cause the pigs will be able to use the excess skimmilk only as a source of energy and not as a high-quality protein supplement.

The lessened value of skimmilk or buttermilk when more is fed than needed is well shown by 2 Ohio tests.[7] Young pigs were fed until they were ready for market on various proportions of skimmilk and corn, in comparison with others fed corn and tankage. When 1 lb. of skimmilk was fed with each pound of corn, skimmilk was worth 51 cents per 100 lbs., but when 3 lbs. of skimmilk were fed per pound of corn, the value was reduced to 30 cents. When the pigs were allowed to drink all the skimmilk they would take in addition to a full feed of corn, each 100 lbs. of the skimmilk was worth only 21 cents.

Because of the high efficiency of milk protein as a supplement to the cereal grains, pigs fed grain and either skimmilk or buttermilk do not require quite as much protein as is advised in the feeding standards.

The proportion of skimmilk or buttermilk that is needed to balance corn or other grain will depend on the age of the pigs. Just after weaning, pigs require so much protein that 4 to 6 lbs. of skimmilk or buttermilk are needed to balance each pound of corn. This is a larger proportion of milk than pigs will usually take when they are full-fed on corn. Therefore, milk should preferably be used at this time in combination with a limited amount of other protein supplements. An excellent combination is corn, skimmilk, and a small amount of wheat middlings or linseed meal (with legume hay in addition for pigs not on pasture).

As the pigs grow older, the proportion of skimmilk or buttermilk needed to balance the ration decreases as follows: Pigs weighing 50 to 100 lbs., 2.5 to 3 lbs. milk to 1 lb. corn; pigs weighing 100 to 150 lbs., 2 to 2.5 lbs. milk to 1 lb. corn; pigs weighing 150 to 200 lbs., 1.5 to 2.0 lbs. per pound of corn; and pigs weighing over 200 lbs. only 1.0 to 1.5 lbs. of milk for each pound of corn. Where barley or wheat is fed in place of corn, only about one-half to two-thirds as much milk is needed for each pound of grain as with corn. Pigs fed corn on good pasture will need only about one-half as much milk for each pound of grain.

If the above amounts of milk are available, there is no need of adding any other protein-rich feed. Adding a protein supplement like tankage to a ration of grain and plenty of skimmilk may increase the rate of gain of pigs a trifle, but the use of the tankage will be uneconomical.[8] On the other hand, if there is not quite enough skimmilk to balance the ration, then it will pay to feed a small amount of some other supplement, like tankage, linseed meal, or wheat middlings.

As the pigs grow older, the proportion of skimmilk or buttermilk needed to balance the ration decreases, but the pigs eat more grain per head daily. Therefore, after pigs reach a weight of 40 to 50 lbs., the weight of milk that is needed per head daily to balance the ration remains about constant. For pigs not on pasture that are full-fed corn and supplied with legume hay in addition, 6 lbs. of skimmilk or buttermilk per head daily will produce rapid and economical gains.[9] The rate of gain may be a trifle more rapid when more is fed, but generally the value of the milk per 100 lbs. will be less.

For pigs full-fed corn on good pasture, a daily allowance of only 3 to 4 lbs. of milk per head is satisfactory.[10] If an abundance of milk is available, the gains can be increased slightly by feeding 4 to 6 lbs. of milk a day, but the milk will then have a lower value per 100 lbs.

When there is a surplus of skimmilk or buttermilk that cannot be utilized by other stock, it does no harm to let swine have a large amount of milk, even all they will drink. In Wisconsin trials young sows allowed 20 to 30 lbs. of skimmilk per head daily during pregnancy had excellent litters.[11] Their pigs were larger and more vigorous than those from sows fed tankage as the protein supplement.

886. Money value of skimmilk or buttermilk for swine.—The value of skimmilk as a protein supplement for swine has been determined in numerous experiments, by comparing a ration of corn and skimmilk with a ration of corn and tankage or some other efficient supplement. To make the comparison reliable, just enough of skimmilk and of the other supplement must be fed to balance the ration properly.

In 12 such experiments pigs not on pasture have been fed corn (usually yellow corn) and skimmilk in comparison with others fed corn and tankage from a weight of about 75 lbs. until ready for market.[12] The pigs fed skimmilk and corn gained 1.36 lbs. a day, on the average, in comparison with 1.24 lbs. for those fed tankage. In these trials each 100 lbs. of skimmilk saved 7.3 lbs. tankage, plus 10.9 lbs., corn, without giving any credit for the more rapid gains produced by feeding skimmilk. The high value of the dry matter in skimmilk is shown by the fact that 100 lbs. of skimmilk, containing only 9.5 lbs. dry matter, replaced 15.7 lbs. of dry matter in corn and tankage.

For young pigs not on pasture, neither corn and skimmilk nor corn and tankage is an ideal ration. These rations can both be improved by adding a small amount of good legume hay. It is therefore important to know the value of skimmilk when it is compared with tankage in an ideal dry-lot ration which includes legume hay. In 6 such experiments fully as good a showing was made by skimmilk as in the experiments mentioned previously.[13] When skimmilk was tested in this critical way, the gains of the pigs fed skimmilk were a trifle more rapid than of those fed tankage. Each 100 lbs. of skimmilk was equal to 7.0 lbs. of tankage plus 11.7 lbs. corn or equivalent.

These 6 trials give the best measure of the value of skimmilk or buttermilk per 100 lbs. when just about enough is fed to balance a ration. From these figures the money value of these dairy by-products under local conditions can readily be found. For example, with tankage at $100 a ton and corn at $1.40 per bushel ($50 a ton), skimmilk or buttermilk is worth about 64 cents per 100 lbs.

An older method often used for valuing skimmilk is to estimate that 100 lbs. of skimmilk are approximately equal in value to one-half bushel of corn. This is a somewhat less accurate basis, for skimmilk replaces both corn and protein supplement, and the prices of corn and supplements do not always rise and fall in the same proportion.

For very young pigs up to 50 or 60 lbs. in weight, skimmilk or buttermilk will have an even higher value than shown in these experiments. Also, the value will be higher when only a very limited amount of skimmilk or buttermilk is fed to pigs in combination with grain and a small amount of other protein supplements.

When considerably more skimmilk or buttermilk is fed than is needed, the additional amount is worth only about one-half as much per 100 lbs. as the quantity that is really needed to balance the ration. Also, the value of these dairy by-products is somewhat less per 100 lbs. for pigs on good pasture than for those in dry lot.[14] This is because good pasture helps furnish some of the nutritive factors that make milk such an excellent feed.

If a ration already contains a sufficient amount of tankage, fish meal, or other efficient protein supplement to balance it properly, it is uneconomical to add skimmilk or buttermilk to it.[15] The other protein supplements should be omitted, or else reduced in amount if there is not enough milk to balance the ration completely.

887. Skimmilk and buttermilk for poultry.—Dairy by-products have high values for poultry. Not only does milk furnish excellent protein, but also its high content of riboflavin is of particular value for poultry. Also, milk supplies niacin, vitamin B_{12}, and certain of the unidentified vitamins. (222) In addition, milk is rich in calcium and phosphorus. The beneficial effect of dairy by-products in poultry rations is partly due to

the effect produced by milk sugar in helping to prevent the development of undesirable bacteria in the digestive tract.

When liquid skimmilk or buttermilk is available, poultry may be allowed to drink all they wish, as a substitute for part or all of the protein supplements usually included in the ration. The amount taken by 100 hens will usually be 12 to 14 quarts a day.

Reasonably good egg production can be secured when hens are fed only grain with all the milk they will drink.[16] Such a ration is much better for hens on good range than for those which are confined.

In summer flies, which are the intermediate host of tapeworms, are apt to be present in large numbers around the vessels in which milk is fed. In Kansas tests the feeding of liquid milk greatly increased the infestation of hens with tapeworms for this reason, but it decreased the number of other worms present in the birds.[17] There was no effect on egg production, but the greater infestation with tape worms might have been more harmful at an early age.

888. Whey.—In making cheese, practically all the casein and most of the fat go into the cheese, leaving in the whey the milk sugar, the albumin, and a large part of the ash. Whey is more watery in composition than skimmilk, containing less than 7 per cent dry matter. Whey from Cheddar and most other types of cheese has about 5.0 per cent milk sugar and 0.3 per cent fat, with only 0.9 per cent protein. Whey from Swiss cheese contains 0.8 to 1.0 per cent fat. To save the fat for butter manufacture, whey (especially from Swiss cheese) is often skimmed at the factories. Skimmed whey is worth slightly less than unskimmed whey.

Whey has only about one-third as much calcium and phosphorus as skimmilk, as whey has but 0.05 per cent calcium and 0.04 per cent phosphorus. It is nearly as rich in riboflavin as is skimmilk.

In feeding whey it is very necessary to bear in mind the fact that most of the protein has been removed, and that whey is not a protein-rich feed, like skimmilk and buttermilk. The milk albumin it does contain is, however, of high efficiency in making good the deficiencies in the proteins of the cereal grains.

Whey is fed chiefly to swine, for which purpose it is worth about one-half as much per 100 lbs. as is skimmilk. It can be used satisfactorily for raising dairy calves when it is fed with a concentrate mixture that is rich in protein. Whey can also be fed to poultry as a source of riboflavin.

Whey should always be pasteurized at the factory to prevent the spread of disease and should be fed under sanitary conditions. Whey soured in clean containers is as valuable as sweet whey, but that from a filthy whey tank may be a very unsatisfactory feed.

889. Whey for dairy calves.—Whey can be successfully used for calf feeding, if it is fed with a suitable protein-rich grain mixture and if it is of sanitary quality. An excellent mixture for feeding with whey is 30 lbs. ground corn, 30 lbs. standard wheat middlings, and 40 lbs. linseed meal.

Two Wisconsin trials show the good results that can be secured with whey under proper conditions.[18] Calves were changed gradually from whole milk to skimmed whey at 3 weeks of age during a period of 10 days. In addition, they were fed clover hay and the protein-rich mixture mentioned previously. The allowance of whey was gradually increased to 14 lbs. per head daily at 6 weeks of age. These calves made normal gains and were vigorous and thrifty, though they did not gain quite so rapidly as calves fed a liberal amount of skimmilk.

890. Whey for swine.—Because of the superior quality of protein in whey, well-grown pigs weighing over 100 lbs. will make excellent gains on a ration of only whey fed with barley or wheat, without any high-protein supplement. For example, in Wisconsin tests such pigs gained even more rapidly on a ration of 7.8 lbs. barley plus what whey they would drink (an average of 18.4 lbs. a day) than others did on barley

and tankage.[19] Likewise, in 2 California experiments pigs fed barley and whey gained nearly as rapidly as those fed barley and skimmilk.[20]

For younger pigs some protein-rich feed, such as linseed meal or wheat middlings, should be added to the grain and whey to balance the ration. It is not necessary to use a protein supplement which furnishes high-quality protein, because of the excellent protein the whey contains, even though the amount of it is small. With corn and whey, a protein supplement should be fed even to pigs over 150 lbs. in weight, for corn has considerably less protein than does barley or wheat. For pigs not on pasture, legume hay should be provided in addition to grain and whey, in order to supply vitamins A and D.

In the Wisconsin trials skimmed whey was worth about one-half as much per 100 lbs. as skimmilk, and the value of whey was even higher in the California trials. Unskimmed whey from American or Cheddar cheese factories will be worth a trifle more than skimmed whey, and unskimmed whey from Swiss cheese factories will have a higher value.

In continental Europe pigs are often fattened on cooked potatoes and whey with a small allowance of grain, and with a protein supplement, at least until they reach a weight of about 130 lbs.[21]

891. Whey for poultry.—Whey in liquid form is not often fed to poultry, but when available, it can be given as a drink or used to moisten the mash. It must be remembered that whey is low in protein and therefore is not a substitute for protein-rich feeds. However, it will fully take care of the riboflavin requirements.

892. Dried skimmilk; dried buttermilk.—Considerable quantities of skimmilk and buttermilk are dried at the factories to produce dried skimmilk and dried buttermilk. Because of their high value in human foods, these products are commonly too high in price to be used largely for stock feeding. A small percentage is often included in poultry mashes, especially for chicks and broilers, and they are also used in calf starters and milk replacers for dairy calves and in pig starters or in mixtures for creep-feeding pigs.

Dried skimmilk sold for human food is now called "nonfat dry milk solids" or "defatted milk solids" under Federal regulations. When sold for livestock feeding it is commonly called dried skimmilk, dried skimmed milk (feeding), dry skimmilk, or powdered skimmilk.

One pound of dried skimmilk or of dried buttermilk has approximately the same composition and feeding value as 10 lbs. of liquid skimmilk or buttermilk, respectively. Dried skimmilk contains an average of 33.1 per cent protein, 51.1 per cent milk sugar, 8.0 per cent minerals, and 1.1 per cent fat. Dried buttermilk is a little lower in protein and appreciably lower in nitrogen-free extract (chiefly milk sugar), but has an average of 6.1 per cent fat. Because of the alkalies used in partially neutralizing very sour cream, dried buttermilk is higher than dried skimmilk in minerals. According to the definition of the American Association of Feed Control Officials, dried buttermilk (feeding) must not contain more than 8 per cent of water or more than 13 per cent of mineral matter, and must have not less than 5 per cent of butterfat.[22]

Dried skimmilk and dried buttermilk are very rich in riboflavin, and their high value in poultry feeding is due largely to this fact.

893. Dried skimmilk; dried buttermilk for dairy cattle.—As is pointed out in Chapter XXVII, dried skimmilk or dried buttermilk is an excellent protein supplement for use in a "calf starter," or calf meal, for raising dairy calves in market-milk and condensary districts, where skimmilk is not available. In such localities calves are also often raised on reconstituted, or remade, skimmilk or buttermilk. This is prepared by mixing dried skimmilk or dried buttermilk with warm water at the rate of 1 lb. to 9 lbs. of water. First mix the dried product to a smooth paste with an equal weight of cold water and then add 8 parts more of warm water. This solution will have practically the same composition as fluid

skimmilk or buttermilk, and can be used like skimmilk in raising calves.

When the reconstituted milk is fed in the same manner and in the same amounts as skimmilk or buttermilk, nearly as good results can be secured with it.[23] The difficulty is that these dried products are often expensive. Changes can be made freely from skimmilk to reconstituted skimmilk or from buttermilk to reconstituted buttermilk, if the supply of the fluid by-products varies from day to day.

Unless the feeding of some whole milk is continued for at least 3 to 4 weeks, the calves are apt not to thrive or to make good gains on such reconstituted milk.[24] This is often the case, even when a supplement is added to supply the vitamin A value that skimmilk lacks.

Recently, surplus dried skimmilk, purchased by the United States Government under the price support plan, was released and sold to feed manufacturers at a price comparable to that of other common protein supplements. A New York test at that time showed that 5 or 10 per cent of dried skimmilk was a very satisfactory substitute for linseed meal in a concentrate mixture for dairy cows.[25] In earlier Wisconsin trials dried skimmilk or dried whey did not have any effect on milk production when included in the concentrate mixture, but dried whole milk caused a small increase in fat test.[26]

894. Dried skimmilk; dried buttermilk for swine.—These dried dairy by-products are generally too expensive to be economical protein supplements for swine, except perhaps for very young pigs. They have a considerably higher value, in comparison with tankage or fish meal, for dairy calves being raised on a minimum amount of milk and for poultry, than they do for swine.

If no fluid skimmilk or buttermilk is available for young pigs at weaning time and for a few weeks afterward, a little more rapid growth results when 2 to 5 per cent of dried skimmilk or dried buttermilk is included in the ration. However, the cost of the gains is generally less when such a protein supplement as the trio mixture is fed, without the dried dairy by-products.[27]

When maximum growth of purebred pigs is desired, regardless of the expense, and no fluid skimmilk or buttermilk is available, excellent results are secured when 5 to 10 per cent of dried skimmilk or dried buttermilk is included in the ration, at least until the pigs reach a weight of 50 to 75 lbs. These dairy by-products should not be self-fed separately, free-choice, for they are so palatable that the pigs will eat much more than they need.

If dried skimmilk or dried buttermilk is used as the only protein supplement, a much larger proportion is needed to balance a ration than with tankage, meat scrap, or fish meal. This is because of the much lower protein content of these dried dairy by-products. For this reason, dried skimmilk and dried buttermilk have been worth only about 90 per cent as much a ton as tankage or fish meal in experiments where they have been used as the only protein supplement, and the cost is generally much higher than this.[28]

895. Dried skimmilk; dried buttermilk for poultry.—These dairy by-products are now used much less commonly in poultry rations than some years ago, because of their wide use in human foods. Instead, dried whey and other whey products are more general in formula poultry mashes.

In early experiments the results with both chicks and laying hens were usually better when dried skimmilk or dried buttermilk was used in the ration than without any dairy by-product. However, with the modern knowledge of animal nutrition, it is now possible to make just as efficient rations without them. In such rations the vitamins and high-quality protein furnished by milk products are supplied by other supplements.[29]

Sometimes 1.0 to 2.5 per cent or more of dried skimmilk or dried buttermilk is included in poultry mashes, especially for chicks and broilers.

896. Dried whole whey; other dried whey products.—Dried whole

whey, also called dried whey, is made by drying whey from cheese manufacture or from the manufacture of casein from skimmilk. It has an average of 12.8 per cent protein and 70.1 per cent milk sugar. One pound of dried whey is equal to 13 or 14 lbs. of liquid whey in nutrients.

Dried whey is especially rich in riboflavin and pantothenic acid, and has a good content of niacin and vitamin B_{12}. It also supplies two of the unidentified B-complex vitamins. (222) Due to its high lactose content, dried whey is very laxative, if too much is included in a ration.

Because of its high riboflavin content, dried whey is used chiefly in poultry feeds.[29] It is also used in some "calf starters," or calf meals. Dried whey is also included in some supplemental mixtures for pigs, especially for young pigs.[30] Its value for pigs seems to be somewhat lower than for poultry. By a special process of fermentation before drying, fortified dried whey is made which is particularly high in riboflavin.

Dried whey-product is the dried product resulting from the partial removal of milk sugar from clean, sound whey.[22] It has more protein but less lactose than dried whey, and is used similarly in poultry rations.

Dried whey solubles is the product resulting from the removal of albumin and the partial removal of milk sugar from whey.

897. Condensed or evaporated dairy by-products.—*Condensed or evaporated buttermilk*, also called "concentrated buttermilk" and "semi-solid buttermilk," is made by evaporating buttermilk until it is reduced to about one-third the original weight. Though condensed buttermilk is semi-solid, it generally contains about 70 per cent water, and fully 3 lbs. are required to equal 1 lb. of dried buttermilk or dried skimmilk in amount of milk solids. It is usually more expensive than an equivalent amount of dried skimmilk or buttermilk, because it must be shipped in water-tight containers and because of the greater cost of transporting the watery product. Similar *condensed skimmilk* is sometimes produced, and also *condensed cultured*, or *soured, skimmilk*.

According to the definitions of the Association of American Feed Control Officials, these condensed products must have not less than 27 per cent total solids.[22] Condensed buttermilk must have not less than 0.055 per cent of butterfat and not more than 0.14 per cent of ash for each per cent of solids.

Condensed buttermilk or condensed skimmilk is used chiefly for poultry feeding, but it has been replaced largely by dried buttermilk or dried skimmilk, because of their lower cost per pound of milk solids. In a study of the cost of producing broilers in Arkansas it was found that the poultrymen who fed condensed milk supplements in addition to the other feed made less profit than those who fed none of these condensed products.[31]

Condensed buttermilk may be used in the same manner as dried buttermilk in making reconstituted buttermilk for feeding dairy calves.[32] However, it takes about 3 lbs. of condensed buttermilk to 7 lbs. of water to equal fluid buttermilk in nutrients. If a more dilute solution is fed, as is often done, the feeding of a given amount of the solution will obviously not produce as good gains as the same weight of skimmilk or buttermilk. The acidity in semi-solid buttermilk sometimes causes calves to scour severely, and it is then necessary to neutralize it with lime water before feeding.

In numerous experiments with pigs, slightly more rapid gains have usually been made when condensed buttermilk has been added to good rations containing no milk product, or when it has been used as a substitute for tankage or other common supplements.[33] However, the gains have been much more expensive. In Wisconsin tests there was no benefit from adding 0.15 lb. of condensed buttermilk (diluted with 30 parts of water) to a ration of corn and the trio supplemental mixture for pigs.[34]

Condensed whole whey is the product resulting from the removal of a considerable part of the water from clean, sound cheese or casein whey.[22] It should contain not less than 62 per cent of total whey solids.

Condensed whey-product is the similar product resulting from the removal of a considerable part of the water and the partial removal of milk sugar from whey. It should have not less than 50 per cent of total whey solids.

Condensed whey solubles is a product resulting from the removal of albumin and the partial removal of milk sugar from whey. These whey by-products are used chiefly for

poultry, but can also be used for dairy calves or pigs.

898. Cheese rind, or cheese meal.—This by-product from the manufacture of processed cheese consists of the cheese trimmings, from which most of the fat has been removed. It contains about 60 per cent protein and 9 per cent fat, thus resembling the best grades of tankage in composition. In Wisconsin tests cheese meal was an excellent protein supplement for pigs or poultry.[35] As it is more expensive than tankage or meat scrap, it had best be used to replace not more than half the amount of these supplements usually fed.

II. Meat and Fish By-products

899. Meat by-products.—The meat by-products used for livestock feeding come from three sources: First, from the meat scrap, fat trimmings, and offal at the meat-packing plants and slaughter houses; second, from meat scrap of butcher shops, hotels, etc.; and third, from dead animals processed for soap grease at rendering plants. The various meat by-products include tankage, meat scrap, meat-and-bone scrap, blood meal, and the different types of bone meal.

900. Meat scrap; meat-and-bone scrap; digester tankage.—Two methods are used in processing meat by-products. In the newer method—the dry-rendering method—the waste meat by-products are cooked in an open steam-jacketed vessel until the moisture has evaporated. Then the fat is drained off, the solid residue is pressed to remove as much of the fat as possible, and the dry residue is granulated or ground into a meal. This product is called *meat scrap, meat meal,* or sometimes dry-rendered tankage. Sometimes meat scrap or meat meal is solvent extracted to remove more of the fat.

In the wet-rendering method, which is older, the raw material is thoroughly cooked by steam under pressure in closed tanks. The fat is then skimmed off, the soupy liquid drained off, and the solid residue pressed to remove as much of the fat and water as possible.

The liquid is evaporated down until it becomes gluey, then being called "stick." This is added to the solid residue, and the mixture dried and ground. This product is designated as *digester tankage,* or *feeding tankage.* It is generally called merely "tankage." The wet-rendering process is being largely replaced by the dry-rendering method, as the latter is more efficient.

The best grade of tankage is usually guaranteed to contain 60 per cent protein. Often partly-dried blood is added before drying, to bring the protein content up to the desired amount. Some digester tankages contain only 55 per cent protein. The tankages produced at small rendering plants may have only 40 to 50 per cent protein.

According to the definitions of the Association of American Feed Control Officials meat scrap or tankage should not contain hair, hoof, horn, hide trimmings, manure, or stomach contents, except in such traces as might occur unavoidably in good factory practice.[22]

Meat scrap usually contains only 50 to 55 per cent protein, but is about equal in feeding value to digester tankage containing 60 per cent protein. This is probably because the protein in meat scrap has a higher nutritive value since it is subjected to less heat. Meat scrap does not have so strong an odor as digester tankage and is lighter in color. It does not contain blood meal or "stick."

When tankage or meat scrap contains so much bone that the phosphorus content exceeds 4.4 per cent, the word "bone" must be included in the name, such as meat-and-bone scrap, or digester tankage with bone.

Certain meat by-products that do not contain enough fat to be used as sources of grease or tallow are dried directly and marketed as high-protein meat meals, or are blended with tankage or meat scrap.

901. Value and use of meat scrap and tankage.—Meat scrap and tankage are used chiefly as protein supplements for swine and poultry. Meat scrap is generally preferred to tankage for poultry.

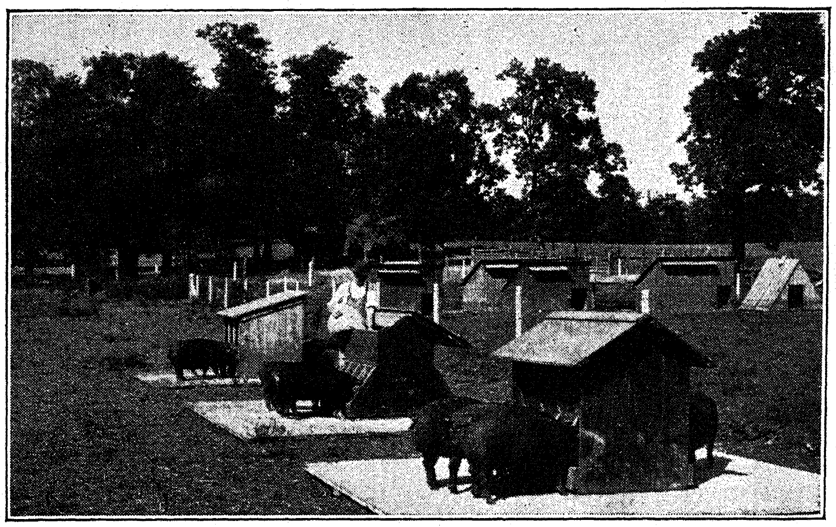
High-grade meat scrap and tankage are not only very rich in protein, but also the protein effectively corrects the deficiencies in the protein of the cereal

grains. These animal by-products are high in lysine, but supply less methionine and tryptophan than does fish meal, and have less tryptophan than soybean oil meal, linseed meal, cottonseed meal, or peanut oil meal. Since corn is very low in tryptophan and the other grains rather low, meat scrap or tankage gives the best results when combined with a protein supplement that is higher in this amino acid.

Meat scrap and tankage are excellent sources of vitamin B_{12} and are rich in niacin and choline. They also supply certain unidentified vitamins that are important in poultry and swine rations. (222) They do not supply vitamin A or vitamin D and are rather low in riboflavin.

Meat scrap and tankage are especially rich in phosphorus and calcium, chiefly because of the bone content.

Meat scrap and tankage do not have the special value for dairy cows, beef cattle, sheep, or horses, that they have for swine or poultry. This is because the kind or quality of protein in the ration is of far less importance for ruminants and for horses. (112) However, meat scrap or tankage may be used for these classes of stock, when they are a cheaper source of protein than such plant-protein supplements as soybean oil meal, cottonseed meal, or linseed meal. While these animals may at first not like the feeds, generally they will soon eat a mixture of concentrates containing the small proportion of a meat by-product that is needed to balance the ration. Occasionally, a certain lot of tankage or meat scrap may prove unpalatable to cattle.



TANKAGE OR MEAT SCRAP CAN BE SELF-FED, FREE-CHOICE

When pigs are self-fed, free choice, on corn and tankage or meat scrap in separate compartments of a self feeder, they eat the proper proportion of supplement to balance the ration. (From Wisconsin Station.)

With dairy cows, beef cattle, and sheep the results are apt to be better when tankage or meat scrap is combined with better-liked supplements, than when used as the only protein supplements.

902. Variations in value of tankage and meat scrap.—The nutritive value of tankage and meat scrap unfortunately varies considerably, depending chiefly on the kind of raw material from which they are produced. If they consist too largely of waste that is high in gristle, connective tissue, or bone, the value will be much lower than in the case of a

product containing more meat. This is because the protein in gristle and connective tissue, and also in bone, is of low value. (121) Moreover, some tankages contain too large a proportion of stick or of blood meal, both of which supply protein of rather low quality. Such poor-quality products may have as high percentages of protein and fat as high-grade tankage or meat scrap.

As it is impossible for the usual purchaser to detect the poor quality by ordinary inspection, it is wise to buy those products which are made by establishments of known reputation for high quality. Occasionally, products are found on the market which are adulterated with such materials as hoof meal, ground hair, leather meal, rumen or intestinal contents, etc.

The meat scrap and tankage produced in recent years have tended to be of lower value than the products made earlier. This is because these by-products usually now have a smaller proportion of hearts, livers, kidneys, beef trimmings, and glandular materials, all of which supply good-quality protein. More of some of these materials are now used for human consumption and considerable amounts are used in dog and cat foods, or for fur animals. This change naturally decreases the value of these animal by-product feeds. It makes it even more desirable than formerly to feed pigs not on pasture one of the efficient supplemental mixtures discussed in Chapter XXXIV, instead of using tankage or meat scrap as the only supplement to grain.

Robison of the Ohio Station has reported that in 9 experiments conducted up to 1920 pigs fed corn and tankage in dry lot made an average gain of 1.30 lbs. and required 389 lbs. feed per 100 lbs. gain.[36] In 16 similar later experiments the daily gain was only 1.02 lbs. and 410 lbs. of feed were eaten per 100 lbs. gain.

On prolonged storage the fat in such feeds as meat scrap, tankage, and fish meal tends to become rancid, through the splitting of free fatty acids from the fat. A high content of free fatty acids in these feeds may be detrimental, probably not because the fatty acids are injurious, but because of destruction of vitamins and other changes which have occurred.

903. Rendering-plant tankage, or reduction tankage.—The rendering plants, which render scrap meat and bones from butcher shops, dead animals, etc., for soap grease, produce tankage of various qualities. This rendering-plant or reduction tankage is used chiefly for fertilizer, but some is fed to stock. The high temperature in the rendering process thoroughly sterilizes rendering-plant tankage, but care is necessary in the plant to prevent contamination of the product by contact with rats, or with particles of incoming material, carried on the shoes of the workers. If some of the raw material has begun to decompose before it is processed, the tankage may be unsuitable for feeding, and may be injurious.

It is not surprising that the results have differed widely in the experiments in which rendering-plant tankage has been compared with high-grade tankage.[37] In some tests low-protein tankage having only 35 to 45 per cent protein has been worth fully as much as high-grade tankage per pound of protein actually contained. However, in other trials much less satisfactory results have been secured with rendering-plant tankage. Safety lies only in purchasing rendering-plant tankage made by a concern that has a reputation for producing a product of good quality.

904. Tankage; meat scrap; meat-and-bone scrap for swine.—For swine feeding, tankage and meat scrap are the most commonly used high-protein supplements of animal origin. For this reason, they have generally been the standards with which other protein supplements have been compared in experiment station tests. These feeds are widely used as supplements for growing and fattening pigs and also for breeding stock.

Tankage and meat scrap are very satisfactory as the only protein supplements to grain for pigs or brood sows on pasture. For swine not on pasture, field-cured legume hay of good quality should

also be included in the ration wherever possible. This provides vitamin A, vitamin D, and other vitamins that may be deficient when swine are fed in dry lot for long periods. The addition of legume hay is especially important for young pigs and brood sows during winter in the northern states. It is shown in Chapter XXXIV that certain protein supplemental mixtures are even more efficient for pigs in dry lot than the combination of tankage and alfalfa or other legume hay.

Though excellent results are generally secured when tankage is used as the only supplement to grain for pigs on good pasture, it is shown elsewhere that combinations of tankage and other supplements may produce more rapid and economical gains, especially when self-fed by the free-choice method. Thus, a mixture of one-half tankage and one-half linseed meal, soybean oil meal, or cottonseed meal is slightly superior for feeding in this manner as a supplement to corn for pigs on pasture.

Meat scrap is somewhat superior to digester tankage having approximately the same percentage of protein.[38] In 6 Ohio trials 55 per cent protein meat scrap was slightly more valuable than 60 per cent protein digester tankage.[39] On the other hand, meat-and-bone scrap of the 50 per cent protein grade is generally worth appreciably less than 60 per cent protein tankage. In 14 trials pigs on pasture, fed such meat-and-bone scrap as the supplement to corn, gained as rapidly as those fed digester tankage, but they required a little more feed per 100 lbs. gain.[40] On the average, 100 lbs. of the meat-and-bone scrap were equal in value to 85.4 lbs. of the higher-protein digester tankage plus 2.5 lbs. of corn.

When pigs are self-fed corn and tankage or meat scrap, free-choice, in separate compartments of a self-feeder, they will usually eat about the correct proportions of these feeds to make a well-balanced ration, no matter whether they are in dry lot or on pasture. Because of the convenience and saving of labor, this method of feeding is popular. Occasionally, pigs either overeat on tankage or else fail to take enough to balance their ration properly. In such cases, it may be necessary to discontinue free-choice feeding and either self-feed them a mixture of ground corn and tankage in the proper proportions or else self-feed the shelled corn and hand-feed the tankage.

When pigs are self-fed such combinations as barley or wheat with tankage, free-choice, they frequently overeat on tankage so much as to increase the cost of the gains decidedly. Free-choice feeding of such combinations is not, therefore, to be recommended generally. Instead, a mixture of the proper proportions of ground grain and tankage should be fed, or the grain may be self-fed and the necessary amount of tankage hand-fed twice daily.

When pigs are hand-fed their rations, it makes no difference whether the tankage is mixed with the other feed in suitable proportions or whether the proper amount to balance the ration is fed separately. There is no advantage in feeding the tankage in the form of a slop or in soaking it.

The proportions of tankage or meat scrap needed to balance various rations for swine are shown in Appendix Table VII.

905. Meat scrap; meat-and-bone scrap; tankage for poultry.—Meat scrap is the most widely used protein supplement of animal origin in poultry feeding and is a common ingredient of poultry mashes. It is well liked by poultry and supplies protein that corrects the deficiencies in the proteins of the cereal grains and their by-products. The proportions of meat scrap generally used in poultry feeding are indicated by the example rations in Appendix Table VII.

The quality of protein in meat scrap containing 55 per cent or more of protein is apt to be better than in meat-and-bone scrap, which is lower in protein content.[41] Tankage can replace meat scrap in poultry rations, but most poultrymen decidedly prefer meat scrap.

906. Tankage or meat scrap for dairy cattle.—Although these animal by-products are not commonly used for dairy cows, they are satisfactory when

they furnish protein at lower cost than do such feeds as soybean oil meal or cottonseed meal.[42] Dairy cows will usually eat concentrate mixtures containing 8 to 17 per cent tankage satisfactorily. Occasionally some cows do not like such a mixture at first, though later they will eat it readily.

The milk production is not increased by substituting tankage or meat scrap for the protein supplements ordinarily fed dairy cattle, and it may even be reduced a trifle. These animal by-products have not affected the flavor or odor of the milk, even when fed 1 to 2 hours before milking.

Meat scrap or tankage can be used as a protein supplement in "calf starters," or calf meals, but had best replace only part of the dried skimmilk, other dairy by-products, or soybean oil meal.

907. Tankage or meat scrap for beef cattle.—Tankage or meat scrap is of much less value for beef cattle than for swine or poultry. In 10 experiments fattening cattle fed either tankage or meat scrap as the only protein supplement gained 0.1 lb. less per head daily than similar cattle fed linseed meal, cottonseed meal, or soybean oil meal as the supplement.[43] Where the selling price of the cattle was reported in these trials, it was slightly less for the cattle fed tankage or meat scrap. While the value of these animal by-products varied widely in these experiments, on the average they were worth less per ton than the plant-protein supplements.

Tankage was also inferior to cottonseed meal or corn gluten meal in Kansas tests in which 1 lb. per head daily of these various supplements was fed to calves and yearlings being wintered on Atlas sorghum silage.[44]

It is best to accustom cattle to tankage or meat scrap gradually by mixing a small proportion at the start with better-liked feeds, such as linseed meal, cottonseed meal, or ground grain. Tankage or meat scrap has given better results with beef cattle when used in mixed protein supplements, combined with such feeds as linseed meal, cottonseed meal, and soybean oil meal.

908. Tankage or meat scrap for sheep.—Tankage or meat scrap can be substituted for such protein supplements as soybean oil meal in feeding sheep. Sheep may not like these animal by-products at first, but after a few days will usually eat the small amount needed to balance the ration, especially if mixed with well-liked feeds. Sometimes fattening lambs tire of meat scrap or tankage toward the end of the feeding period.

The results of experiments in which either digester tankage or meat scrap has been used as the only protein supplement for fattening lambs have differed somewhat.[45] In some of the trials the results have been fully as good or even slightly better than with cottonseed meal or linseed meal, but in other tests the gains have been more rapid on the latter supplements.

909. Tankage or meat scrap for horses.—One to 2 lbs. a day of either of these feeds, or 1 lb. of blood meal, is sometimes useful for run-down, thin horses. As these feeds are not liked by horses, they must be mixed with palatable feeds.

910. Blood meal; blood flour.—*Blood meal*, or dried blood, is made from the blood collected at packing plants. It is first heated until it is thoroughly coagulated; the excess water is then drained off; more moisture is removed in a press; and finally, the solid residue is dried and ground.

Blood meal is the highest in protein of all the packing-plant by-products, containing over 80 per cent. However, the protein is less digestible and of much poorer quality than that in high-grade tankage or meat scrap. Blood meal is low in calcium and phosphorus, thus differing again from tankage or meat scrap. It is used chiefly in "calf starters," or calf meals, for raising dairy calves on a minimum of milk. Blood meal is not usually liked by calves at first, and if it is used as the chief protein supplement in a calf meal, it may be difficult to get them started on it.

Sometimes blood meal is used in poultry feeds, but it is unpalatable to

poultry and is inferior to meat scrap in value.[46] Tankage is usually better and cheaper for young pigs.[47] In a Massachusetts test 10 per cent of blood meal was a fairly good substitute for other protein feeds in a concentrate mixture for dairy cows.[48]

Blood flour, or soluble blood meal, is produced by special processes, and is more soluble than ordinary blood meal. It is considered preferable in calf meals, but in an Ohio trial ordinary blood meal equaled soluble blood flour.[49]

911. Hoof and horn meal.—Experiments have shown that when animal hoofs and horns are ground to an extremely fine powder in a ball mill, the product can be digested by animals and can be used to replace part of the usual protein supplements for poultry. The product seems to be decidedly variable, however, and sometimes does not give satisfactory results.[50]

912. Feather meal.—Feather meal, or hydrolized feathers, is a new product made by treating under high steam pressure the feathers from slaughtered poultry. It has over 80 per cent protein, and according to the definition proposed by the Association of American Feed Control Officials, should have 70 per cent digestible protein.[22] The results of the few trials reported with feather meal have differed, apparently due to variations in quality.[51]

Feather meal properly made can apparently replace part of the ordinary protein supplements in rations. Satisfactory results have been reported with 2 to 5 per cent in a broiler mash. Feather meal seems to supply vitamin B_{12} and one of the unidentified factors needed by chicks. (**222**)

913. Liver meal.—Various types of liver meal, made chiefly from animal or fish livers, are used primarily as vitamin supplements, but also supply high-quality protein. *Animal liver meal* should be made entirely from liver. *Animal liver and glandular meal* is made from liver and other glandular tissue and at least 50 per cent of the dry matter should be from liver.[22] Similar products are made from fish by-products.

Liver meals are used chiefly as vitamin supplements in poultry mashes or in special feeds for pet stock and fur animals, because of the content of riboflavin and other B-complex vitamins. Adding 2 per cent of liver meal to a ration for very young pigs in dry lot may increase the thriftiness and gains, but may be uneconomical, because of the high price.[52]

914. Low-grade animal fat.—Due in large part to the wide use of detergents in place of soaps in this country, there has recently been a surplus of low-grade animal fats, produced in the meat and rendering industries. (**134**) As a result, the prices of these tallows and greases have declined to levels that make their use in formula feeds, or mixed commercial feeds, practical. The use of these fats is discussed in Chapter V and in the chapters dealing with the different classes of stock. To prevent the development of rancidity in the fat and resulting destruction of vitamins in the feed, an effective antioxidant should be added to the fat.

915. Paunch fluid, dried.—In Wisconsin tests a product rich in B-complex vitamins was prepared experimentally by pressing out and drying the fluid that could be pressed from the paunch contents of cattle or sheep at a slaughter house.[53] It was about as rich as dried skimmilk in riboflavin.

916. Poultry by-product meal.—This by-product of poultry processing plants consists of the ground, dry-rendered, clean, wholesome parts of the carcasses of slaughtered poultry, such as head, feet, undeveloped eggs, gizzard and intestines, exclusive of feathers and gizzard and intestinal contents, except in such trace amounts as might occur unavoidably in good factory practice.[22] Limited data indicate that it may be a satisfactory substitute for meat scrap.[54]

917. Fish meal.—Years ago most of the fishery wastes were either used to make fish meal for fertilizer or were not utilized at all, but dumped in the sea. Because of the numerous experiments which proved the high value of fish meal for swine and poultry, the production of fish meal has increased until it has become an important protein supplement.

Several types of fish meal are made, differing both in the raw material used and in the method of drying. Menhaden fish meal is the most common kind in the eastern states. This is made in processing menhaden herring (a very fat fish not suited for food) for fish oil and fish meal. White fish meal is made chiefly

from the cuttings or waste of the cod and haddock industry, not including the entrails, which, except the livers, are dumped at sea. Other fish meals are made of waste from sardines, herring, salmon, tuna, etc.

At first, fish meal was nearly all dried in so-called "flame driers," in which the material was exposed to high temperatures. This method has been largely replaced by drying in steam-jacketed drums, often under partial vacuum, to lower the temperature. Vacuum-dried fish meal is superior to flame-dried fish meal made from the same material, as it has a higher content of vitamins and the protein is more digestible.

In the case of fish cuttings that are high in fat or oil, most of the oil is expressed from the product. A high fat content in fish meal is undesirable, as such fish meal may produce a fishy taste in eggs, meat, or milk. Also, fish meal high in fat is more apt to become rancid on storage.

918. Nutritive value of fish meals. —Fish meals differ somewhat in nutritive value, depending on the type of raw material used, the method of drying, and the care taken in the process. But few direct comparisons have been made of the various kinds of fish meal, and therefore only general statements can be given concerning their relative feeding value.

Fish meal of good quality has an especially high value for swine and poultry, because of the excellent quality of protein it supplies. However, the protein quality in different samples of fish meal varies decidedly. In more than a hundred samples of various commercially produced fish meals recently tried in California experiments, only about half were rated as good in protein quality.[55] In these tests sardine fish meals, which comprised the greatest number of samples, were generally of high quality.

Apparently, some fish meal producers should use much more care in making their product. If decomposition of the fish waste occurs before it is processed, the fish meal may be injurious and entirely unsuitable for feeding. Obviously, much more care must be taken to prevent decomposition in the production of fish meal for stock feeding than in making fish meal for fertilizer. Certain fish waste is too high in salt to be used to make fish meal for feeding, unless the salt is removed from the product.

Fish meal is very rich in protein, containing 60.9 per cent, on the average. Also, the protein of good-quality fish meal is of high nutritive value, tending to be more efficient than the protein of tankage or meat scrap as a supplement to the grains. If fish meal contains too large a proportion of fish heads, the value of the protein is decreased, because much of the protein in the heads is less digestible and of lower nutritive value than the protein in the flesh.

Herring fish meal is the highest in protein content, averaging 72.5 per cent. Sardine, menhaden, and white fish meal all average above 60 per cent in protein, while fish meal from redfish, salmon, and tuna usually has somewhat less protein.

Fish meal usually has 6 to 10 per cent of fat, but some fish meal is now made which has only 3 to 4 per cent fat.

Because of the bones it contains, fish meal is high in calcium and phosphorus. It has an average of 5.36 per cent calcium and 3.42 per cent phosphorus, with a total mineral-matter content of 18.3 per cent. It should also be noted that fish meal usually contains an appreciable amount of iodine. However, in regions where there is an iodine deficiency for livestock, iodine can readily be supplied at less expense in the form of iodized salt. (**170**)

Fish meal is one of the richest sources of vitamin B_{12} among common feeds and also of one of the unidentified vitamins required by poultry. (**222**) It is also fair in riboflavin content and has considerable niacin. Fish meal processed under partial vacuum may contain considerable vitamin A and vitamin D, but other fish meals may have little of these vitamins.

Some have hesitated to use fish meal for stock feeding, fearing that it might cause a fishy flavor in eggs, meat, or milk. In the numerous feeding experiments

with fish meal no injurious effect has been produced when good fish meal, not unduly high in fat, has been fed in such amounts as were needed to balance the ration. If a larger allowance of fish meal is fed there may be danger of producing a fishy flavor.

919. Fish meal for swine.—Numerous experiments have shown that fish meal of good quality is even superior to tankage or meat scrap as a protein supplement for swine. Fish meal produces very satisfactory results when used as the only protein supplement to grain for pigs or brood sows on pasture. For swine not on pasture, field-cured legume hay of good quality should be included in the ration, if possible, to make sure that there is a plentiful supply of vitamin A, vitamin D, and the B-complex vitamins. It is shown in Chapter XXXIV that the results are especially good when fish meal is used in one of the efficient trio-type supplemental mixtures, which includes alfalfa or other legume hay and also a protein supplement of plant origin, such as linseed meal or soybean oil meal.

When fish meal is used in place of tankage or meat scrap in a trio-type supplemental mixture, there is not much difference in the value of these protein supplements. For example, in 11 New York and Ohio experiments pigs fed fish meal in trio-type supplemental mixtures gained an average of 1.51 lbs. a day and required 383 lbs. of feed per 100 lbs. gain.[56] Similar pigs fed tankage or meat scrap in the trio-type mixtures gained 1.47 lbs. a day and required 385 lbs. of feed per 100 lbs. gain. Fed in this manner, the fish meal was worth only about 5 per cent more per ton than tankage or meat scrap.

When fed as the only protein supplement to grain for pigs not on pasture, fish meal is decidedly superior to tankage or meat scrap. In 18 trials pigs fed fish meal as the only protein supplement to corn in dry lot gained 1.68 lbs. daily, on the average, and required 349 lbs. corn and 35 lbs. fish meal per 100 lbs. gain.[57] Others fed digester tankage gained 1.46 lbs. a day and required 381 lbs. corn and 37 lbs. tankage per 100 lbs. gain. In these trials each 100 lbs. of fish meal was equal in value to 106 lbs. digester tankage plus 91 lbs. corn, without considering the advantage of the more rapid gains.

Fish meal has also been superior to tankage when fed as the only supplement to corn for pigs on pasture, but the difference in value of the two supplements has not been so great as for pigs in dry lot. In 11 experiments with pigs on pasture, the average daily gain has been 1.59 lbs. on fish meal and corn, in comparison with 1.49 lbs. on tankage and corn.[58] In these trials each 100 lbs. of fish meal has been equal in value to 113 lbs. tankage plus 19 lbs. corn.

Especially good results are secured with certain complex protein supplements that include both fish meal and also meat scrap or meat-and-bone scrap.

Only a few comparisons have been made of the relative values of the different kinds of fish meal, but they are all apparently very satisfactory when made from raw material of suitable quality for feeding and when not unduly high in fat.[59]

If pigs are fed considerably more fish meal than is needed to balance the ration, or if the fish meal is unduly high in fat, a fishy flavor may be produced in the pork.[60]

920. Fish meal for poultry.—Good fish meal is an excellent protein supplement for poultry, the quality of the protein being somewhat superior to that in meat scrap.[61] Also, the B-complex vitamin content is important. However, most fish meals are not so palatable to poultry as meat scrap, and therefore not more than 5 to 10 per cent should be included in the ration.

Fish meal does not give a fishy flavor to the flesh of chickens or to eggs when the fish meal is of good quality and when the ration contains no more than 5 to 10 per cent. Fish meal may affect the flavor of turkeys if it is fed during the fattening period. It is therefore best to feed no fish meal for at least 8 weeks before marketing them.[62]

921. Fish meal for cattle, sheep, and horses.—If fish meal is a cheaper source of protein than protein supplements of plant origin, it can be used economically for cattle or sheep. However, for these classes of stock a pound of protein in fish meal usually has no higher value than in such supplements as linseed meal, soybean oil meal, or cottonseed meal. Also, fish meal is often not palatable to cattle or sheep. They will usually become accustomed to a concentrate mixture containing 10 to 15 per cent of fish meal, but occasionally animals will refuse to eat such a combination.

In most of the experiments in which fish meal has been fed to dairy cows, the yields of milk and fat have been satisfactory, but in some instances the fish meal has slightly decreased the percentage of fat in the milk.[63] The same effect is produced by cod-liver oil and certain other fish oils. Often the mixture containing fish meal has been less palatable to cows than the usual type of dairy concentrate mixture. Fish meal is sometimes used to furnish part of the protein in calf meals, or "calf starters," for dairy calves being raised on a minimum amount of milk.

Fish meal of good quality has produced satisfactory results when used as a protein supplement for fattening lambs or fattening cattle.[64] It is occasionally fed to horses.

922. Condensed fish solubles; homogenized condensed fish.—*Condensed fish solubles* are made by evaporating to a semi-solid condition the watery solution which is expressed, along with the oil, when fish or fish wastes are processed. They have about 50 per cent dry matter and 30 per cent protein. The chief value of condensed fish solubles is due to the high content of certain B-complex vitamins. They may contain about as much riboflavin as dried skimmilk; they are rich in pantothenic acid, especially high in niacin, and even higher than fish meal in vitamin B_{12}. They also provide one of the unidentified vitamins important in poultry feeding. A small amount of dried fish solubles is also made.

Experiments have shown that for swine[65] or poultry[66] kept continuously in confinement, with no access to green feed, adding 2 to 3 per cent or more of condensed fish solubles decidedly improves rations that have little or no protein supplement of animal origin.

Homogenized condensed fish, or liquid fish, is a partially dehydrated product made from fish and/or fish cuttings from which part of the oil has been removed. It should contain not less than 50 per cent of dry matter, exclusive of any added salt. It is used in the same way as condensed fish solubles.

923. Crab meal.—Crab meal is made from the waste of the crab industry and contains the shell, viscera, and parts of the flesh. It is much lower in protein and higher in mineral matter (chiefly calcium carbonate) than is fish meal, for it has an average of 40.9 per cent mineral matter and only 31.6 per cent protein. For poultry it is a satisfactory substitute for fish meal, when it is used in combination with other protein supplements and if the calcium content of the ration is adjusted properly.[67] It requires about 4.0 lbs. of crab meal to replace 2.5 lbs. of fish meal.

In a Pennsylvania trial crab meal was a satisfactory protein supplement for pigs, but in a South Carolina test pigs would not eat enough of a mixture of crab meal and cottonseed meal to balance their ration properly.[68]

924. Gelatin.—The protein in gelatin has a low nutritive value, and therefore gelatin is not satisfactory as a substitute for tankage in stock feeding.[69] A by-product composed chiefly of gelatin, called "alba blood," made from discarded printers' rolls, has been sometimes used as an adulterant in tankage.

925. Shrimp meal.—Shrimp meal is the dried waste of the shrimp industry, consisting of the heads and hulls (or shells), and perhaps some whole shrimp. It is steam-dried or dried in the sun, in which case salt is commonly added to prevent spoilage. According to the regulations of the Association of American Feed Control Officials, it must not contain more than 7 per cent of salt, and if it has more than 3 per cent, the amount must be stated.[22]

Shrimp meal has an average of 46.7 per cent protein and 27.8 per cent mineral matter. Though the protein content is lower than in fish meal, the protein is apparently

of good quality. Because of the very high percentage of mineral matter, it is best to use shrimp meal in combination with other protein supplements.

Shrimp meal is a satisfactory protein supplement for swine, and especially good results were secured in Louisiana and Mississippi experiments with combinations of half shrimp meal and half soybean oil meal or cottonseed meal.[70] Shrimp meal is also a good protein supplement for poultry rations, particularly when used in combination with other protein supplements.[71]

For dairy cows shrimp meal was a satisfactory substitute for cottonseed meal in Louisiana tests.[72] When the shrimp meal was gradually introduced into the ration, mixtures containing 10 to 19 per cent shrimp meal were readily eaten.

926. Shark meal.—Shark meal apparently differs widely in value, depending on the quality of the raw material and the method used in manufacture. In Florida trials shark meal, having an average of 78 per cent protein, was a satisfactory protein supplement for pigs and for dairy calves, but in tests with chicks the results differed widely.[73]

In Washington experiments dry-rendered meals made from dogfish (a small kind of shark) were of low value for poultry, while wet-rendered dogfish meal gave better results.[74] In shark meal an appreciable part of the nitrogen is in the form of urea, which is valueless for swine and poultry. (129)

927. Starfish meal.—Starfish meal, having about the same content of protein and mineral matter as crab meal, can be made from the entire starfish.[75] This may be used for poultry in the same manner as crab meal. Starfish are a serious problem in the oyster industry, as they eat the young oysters.

928. Whale meal; whale solubles.—*Whale meal,* similar in composition and value to tankage or meat scrap, is made from the clean, undecomposed flesh of whales, most of the fat being expressed.[76] The protein and mineral matter content will vary considerably, depending on the proportion of bone present. Some whale meal has not been of satisfactory quality for feeding, because of decomposition before the material was processed or the use of unsatisfactory methods of preparation.

Whale solubles, somewhat similar to condensed fish solubles or homogenized condensed fish in composition, were satisfactory in Australian tests when supplying most of the animal protein in a poultry ration.[77]

III. Sugar-Factory By-products

929. Cane molasses.—Cane molasses for feeding, also called "blackstrap" or "feeding cane molasses," is a by-product in the manufacture of sugar from sugar cane. It is the residual molasses remaining after as much sugar as possible has been crystallized from the juice which has been purified and then condensed by evaporation. The other by-products from sugar cane are the sugar cane tops and the bagasse. These are sometimes used for stock feeding, as has been pointed out in Chapter XVIII.

In addition to the quantity of cane molasses produced in our southern states, a large amount is brought into this country from other regions making sugar from cane. Only about 10 per cent of the cane molasses that is used for feeding is purchased as molasses by stockmen. The rest is used in the manufacture of formula feeds (commercial mixed feeds). A greater amount of cane molasses is utilized for the production of alcohol, yeast, and other fermentation products than is used for feeding.

Cane molasses is much relished by stock, and it also has a mild laxative effect that is beneficial when the other feeds are constipating. Cane molasses usually has about 55 per cent of sugars, which furnish most of the feeding value.

The usual kind of cane molasses has only 3.0 per cent protein, and this consists largely of compounds having low nutritive value. Also, when any considerable amount of molasses or sugar in other forms is added to a ration for cattle or sheep, the digestibility of the protein and other nutrients of the ration is apt to be decreased. (103) As a result, cane molasses has, on the average, a negative value for digestibility of protein, and in Appendix Table I is rated as supplying no digestible protein. Because of these conditions, it is important that ample protein be furnished by the rest of the ration when large amounts of molasses are fed.

Molasses made from sugar cane grown on muck soil high in nitrogen, as in drained areas of the Florida Ever-

blades, may have 9 per cent of crude protein.[78]

The digestibility of the protein or other nutrients in a ration is usually not decreased when only a small amount of molasses is added to a well-balanced ration. Thus, in Missouri trials the digestibility was increased, rather than decreased, when not more than 2 lbs. of molasses per head daily was added to a dairy ration.[79] In a New York trial there was no decrease in digestibility of protein when one-fourth of the corn in a ration for dairy heifers was replaced by molasses, but a larger proportion of molasses caused a decrease.[80]

Chiefly because cane molasses has an average of 26.6 per cent water, it supplies but 53.6 lbs. total digestible nutrients per 100 lbs., which is only two-thirds as much as in corn grain. Cane molasses weighs about 11.7 lbs. per gallon, and therefore approximately 171 gallons make a ton.

Cane molasses is rich in niacin and pantothenic acid, but is low in thiamine and riboflavin. It has little or no vitamin A or vitamin D.

Molasses has the highest value per pound when a small amount is used to induce stock to eat roughage of rather poor quality with less waste of the stems and coarser parts than there would be otherwise. For this purpose it is often diluted with 1 to 2 parts of water and sprinkled over the roughage. When thus fed, molasses may be worth fully as much or even more than corn or other grain. When molasses is added to a ration made up of feeds that are all palatable, it is generally worth considerably less per 100 lbs. than corn or other grain. This is because it supplies only about two-thirds as much total digestible nutrients per pound as does grain.

Cane molasses is fed most commonly to dairy cows, beef cattle, sheep, and horses, but may be also fed in limited amounts to swine and poultry.[81] When molasses is very cheap, it is sometimes self-fed, especially to fattening cattle.

Cane molasses is used in many formula feeds, or commercial mixed feeds, especially those for cattle and horses. It not only adds to the palatability of the feeds, but it is also often one of the cheapest sources of carbohydrates for the

MOLASSES IS A POPULAR INGREDIENT OF MIXED FEEDS

About 90 per cent of the cane molasses that is fed to livestock in this country is used in the manufacture of formula feeds, or commercial mixed feeds. These fattening cattle are eating a formula feed containing molasses.

feed manufacturer, who can use it in tank-car lots. Molasses is a good dust inhibitor in ground mixtures, and it is a good binder in making pelleted feeds.

When molasses must be shipped in barrels, the cost is much greater than in tank cars. It is therefore frequently expensive for the individual farmer, though it may be cheap at a central feed-mixing plant. Farmers who desire to secure molasses as cheaply as possible should cooperate in arranging with their local feed dealer to order a tank car of molasses. It can readily be hauled direct from the car to the farms in whatever containers may be available, such as well-cleaned, second-hand oil drums. In cold weather it may be necessary to warm the molasses by passing steam through the coils in the tank car, so the molasses will flow satisfactorily.

930. Beet molasses.—In making sugar from sugar beets, the beets are washed and cut into thin strips. Next the juice is thoroughly extracted by means of warm water, leaving the by-product known as wet beet pulp, which is discussed later. After the juice is purified it is evaporated until the sugar crystallizes, and the sugar is separated from the residual molasses by centrifuges. This beet molasses still contains a large amount of sugar, along with mineral salts and other constituents.

Most of the beet molasses is treated further in the Steffen's process to recover more sugar. Some is treated in both the Steffen's process and also in the barium, or Johnstown, process to secure still more sugar. The residual molasses remaining from these processes contains about as much nutrients as untreated beet molasses and has a similar feeding value.

In the barium process, molasses is produced at two stages in the process. These, called A and B molasses, are combined for livestock feeding as C molasses.[82] Some of the A molasses or other beet molasses is processed to separate glutamic acid or sodium glutamate, used for human food flavor enhancement. A by-product from this process, called condensed beet solubles product, or MC 47, is used for feeding. (940)

Beet molasses has as much sugar as cane molasses and is considerably higher in crude protein, but much of this consists of simpler compounds than protein. Beet molasses and beet pulp are very low in phosphorus. When these beet by-products form any large part of the ration, it is therefore necessary to feed a phosphorus supplement.[83]

When properly used, beet molasses has fully as high a feeding value as cane molasses. However, it is much more laxative than cane molasses, on account of the high content of certain alkaline salts and other laxative substances. Stock should therefore be accustomed to beet molasses gradually, and the amounts fed should be strictly limited.

The maximum amounts of beet molasses advised by various authorities for animals accustomed to the feed are as follows, daily *per 1,000 lbs. live weight:* Dairy cows, 2.5 to 3 lbs.; fattening cattle, 4 to 5 lbs.; fattening sheep, 3 to 5 lbs.; driving horses, 2.5 lbs.; draft horses, up to 4 lbs. or even more; and fattening swine, 5 to 10 lbs. Breeding animals should be given smaller allowances than those being fattened, and the amount should be materially reduced 6 weeks before the young are born. As in the case of cane molasses, beet molasses is used in various mixed feeds, especially in alfalfa-molasses feeds. Much of the beet molasses is used in producing dried molasses-beet pulp. (938)

931. Cane molasses; beet molasses for dairy cattle.—When molasses is added to a good dairy ration made up of palatable feeds, it is usually worth somewhat less than corn, pound for pound, but under special conditions the value may be higher. In two Wisconsin trials when 10 per cent of cane molasses was added to a mixture of palatable concentrates, the milk production was practically the same as on the mixture without molasses. In these trials the molasses was worth 89 per cent as much per pound as ground corn.[84]

When a larger proportion of molasses is fed dairy cows, the value of the molasses is apparently much lower. In a New Jersey experiment the milk and fat

yields of cows were markedly reduced when molasses replaced one-half the total digestible nutrients in the grain in the check mixture.[85]

In a New York trial with growing dairy heifers fed good hay or such hay and corn silage, up to 6 lbs. of molasses per head daily produced satisfactory gains, when the amount of protein supplement was increased to make good the lack of protein in cane molasses.[86] The molasses replaced two-thirds the weight of corn, corresponding to the difference in total digestible nutrients.

In the New York trials the gains were much poorer on a ration of low-quality, late-cut hay, molasses, and soybean oil meal, than when corn replaced the molasses on an equal total digestible nutrient basis. Very unsatisfactory results were secured on a ration of the poor hay, molasses, and urea, but they were somewhat better when corn replaced part of the molasses. (129)

Chiefly because of the palatability and appetizing effect of molasses, a considerable proportion of the formula, or mixed, dairy feeds contain 5 to 10 per cent of molasses or more. Feeding much molasses to young calves is apt to cause scours.

To induce cows on official test to consume more feed, molasses is frequently added to their rations, often being added to the water in which dried beet pulp is soaked. In trials by the United States Department of Agriculture with cows heavily fed on official test, molasses thus added to a good ration containing corn silage and legume hay slightly increased the consumption of feed and the production of milk.[87] Except from the standpoint of the value of the increased records, the feeding of molasses was not economical.

In sugar-cane growing regions, cane molasses is often so cheap that it is an economical substitute for part of the grain for dairy cows or heifers. In Hawaiian experiments during 7 years it satisfactorily replaced one-quarter of the concentrates usually fed dairy cows.[88]

DAIRY HEIFER BARN AT CORNELL UNIVERSITY

Experiments to determine the value of cane molasses for dairy heifers were conducted with these heifers. (From New York State College of Agriculture, Cornell University.)

Though some Hawaiian dairymen believed that the continued feeding of considerable amounts of molasses would injure the breeding efficiency of the cows, there was no such effect.

Beet molasses is equal to cane molasses in value for dairy cows, except that too much must not be fed, because of its laxative effect.

932. Cane molasses; beet molasses for beef cattle.—In sugar-cane growing districts cane molasses is widely used for beef cattle, as it is often decidedly lower in price per ton than grain. Also, in other parts of the United States cane molasses shipped in tank cars has often been much cheaper than grain during recent years.

Under such conditions cane molasses is an economical substitute for part of the grain in rations for beef cattle. In the sugar-beet districts of the western states beet molasses is a popular feed for fattening cattle. When not fed in excessive amounts, beet molasses is worth about as much per ton as cane molasses for beef cattle.[89]

Molasses is included in a large proportion of the formula feeds, or commercial mixed feeds for beef cattle, because of its palatability and the prevention of dustiness.

The best results are generally secured when molasses replaces not more than about one-half of the concentrates usually fed, and one should be sure that the ration provides plenty of protein.

If the roughage is of poor quality, sprinkling diluted molasses over it will frequently induce cattle to eat more of it than otherwise. Adding a small amount of molasses to a ration with poor roughage for fattening cattle may be beneficial, even if the molasses is not fed on the roughage. For example, in 3 Ohio experiments the gain of fattening steers was increased an average of 0.29 lb. by the addition of 1 lb. cane molasses to a full feed of corn-and-cob meal, fed with 1.5 lbs. soybean oil meal and with late-cut, weathered timothy hay for roughage.[90] Thus fed, the molasses was worth more than corn-and-cob meal per pound. Differing from these results, in a Texas trial the gain of fattening cattle was slightly reduced by feeding 2 lbs. of cane molasses in place of 1.5 lbs. milo grain in a ration of ground milo, cottonseed meal, and only cottonseed hulls or ground cotton gin trash for roughage.[91] In this trial the molasses had a very low value.

In southern experiments cane molasses has had a somewhat higher value for fattening cattle than indicated by its total digestible nutrient content when added to such a ration as cottonseed meal with hay, silage, or silage and hay for roughage. In 12 such experiments the addition of 3.5 lbs. of molasses per head daily increased the average daily gains 0.18 lb., and 100 lbs. of molasses replaced an average of 20 lbs. cottonseed meal, plus 88 lbs. hay and 79 lbs. silage.[92]

When cane molasses is cheap, sometimes it is self-fed to fattening cattle on pasture. Better gains are produced and the molasses has a higher value, when it is fed along with some grain than when molasses alone is fed. For example, in 3 New York trials yearling steers self-fed cane molasses alone on good pasture ate an average of 11.2 lbs. molasses a day and gained 1.6 lbs., in comparison with 2.4 lbs. for others full-fed ground corn, and eating 12.9 lbs. corn a day.[93] Other steers fed 6.3 lbs. of corn a day and self-fed molasses in addition gained 2.1 lbs. a day.

When fed in combination with corn, molasses was worth 72 per cent as much as corn per pound, but when it was the only concentrate its value was only 50 per cent of that of corn.

In Florida trials cane molasses has been compared to ground snapped corn, including the husks, for fattening steers on excellent pasture on drained land in the Everglades.[94] Fair gains were made by cattle self-fed molasses on such pasture and the molasses was worth about 80 per cent as much as ground snapped corn.

In 7 Nebraska experiments with beef calves wintered on corn silage, protein supplement, and a small amount of corn grain, the rate of gain was the same

when 1 lb. of cane molasses was substituted for 0.7 lb. of the corn grain.[95]

When beet molasses is substituted for part of the grain in rations for fattening cattle, it is usually worth somewhat less per ton than grain. In such experiments the value of beet molasses has ranged from 75 to about 100 per cent of that of grain.[96]

933. Adding molasses to an excellent ration.—Cattle feeders have been much interested in knowing definitely whether or not it would pay to add a small amount of molasses to an already excellent ration for fattening cattle, such as grain, legume hay, corn silage, and protein supplement. The statement is sometimes made that the addition of molasses will appreciably increase the gains and the selling price of the cattle, and that molasses, thus fed, will be worth more per ton than corn.

Many experiments have been conducted to determine the effect of adding cane molasses to well-balanced rations made up of palatable feeds. In 29 trials the addition of an average of 2.2 lbs. cane molasses per head daily to an excellent ration has made only a trifling increase in the rate of gain (an increase of only 0.04 lb. per head daily.) [97] The molasses-fed cattle sold for a slightly lower average price than the others, and they required more concentrates for 100 lbs. gain. Considering all factors, cane molasses was actually worth only 54 per cent as much per ton as grain in these many experiments.

The results have been similar when larger amounts of molasses have been added to rations made up of palatable feeds, or when molasses has been thoroughly mixed with chopped hay or other feeds. Even when molasses has been added to a palatable ration during only the latter part of the fattening period, there has been no advantage from such use.

These numerous experiments show definitely that there is no advantage in adding cane molasses to a palatable ration for fattening cattle, unless the cost of molasses is much less per ton than that of grain. It must be borne in mind that the no-molasses rations in these trials were generally made up of feeds of high quality and that the feeding was done by experienced stockmen. Under less favorable conditions it seems probable that the value of cane molasses in comparison with grain would at least be proportional to the amount of digestible nutrients supplied. This is 67 per cent of the amount furnished by No. 2 grade dent corn.

Molasses seems to have the highest value per ton when added to such a ration as cottonseed meal and cottonseed hulls or other rather low-grade roughage, and less value when added to a ration containing a large amount of silage.

934. Cane molasses; beet molasses for sheep.—Cane molasses or beet molasses is sometimes added to the rations of sheep, especially fattening lambs. Molasses has the highest value in a fattening ration if not more than one-third to one-half pound is fed per head daily. This serves as an appetizer and usually increases the gains slightly. Molasses does not produce satisfactory gains if used as the entire substitute for grain.

When replacing part of the grain for fattening lambs in a ration made up of palatable feeds, molasses is usually worth somewhat less than corn or other grain, because of the lower content of digestible nutrients. If a small amount of molasses is fed as an appetizer or to get lambs to clean up rather inferior hay or other dry roughage, it may be worth fully as much as grain per pound.[98] Cane molasses and beet molasses probably have about the same value for sheep, when containing equal percentages of sugar.[99]

In feeding molasses to sheep, it is usually poured in the grain troughs as a broad "ribbon" or is mixed thoroughly with chopped hay or other roughage. Care must be taken that the wool does not become smeared with molasses.

In Wisconsin experiments lambs fed a concentrate mixture containing 10 per cent cane molasses gained a trifle more than others fed a similar mixture having no molasses.[100] However, in producing gain in weight the value of the molasses was much lower than that of corn. Similarly, in North Dakota trials cane mo-

lasses had a much lower value per pound than corn when 10.5 per cent of molasses was added to rations for fattening lambs.[101]

The value of beet molasses for fattening lambs is shown by the results of 20 trials in each of which one lot of lambs was full fed a good ration without molasses and another lot received molasses in addition.[102] The addition of 0.32 lb. molasses per head daily increased the gain a trifle on the average, and each 100 lbs. of molasses saved 63 lbs. grain or other concentrates and 30 lbs. of hay or hay equivalent in other roughage. With feeds at representative prices, 100 lbs. of molasses were equal to about 78 lbs. of grain, not considering the slight advantage in rate of gain.

935. Molasses for horses and mules.—Molasses is well liked by horses and mules, and they are sometimes fed a quart or so a day as an appetizer or conditioner, even when molasses is higher in price than grain. Diluted molasses may be sprinkled over rather coarse or unpalatable hay so that it will be cleaned up better.

In sugar-cane regions cane molasses is often the most economical source of carbohydrates for work animals. The molasses is usually mixed with other feeds, but is sometimes fed in troughs. As much as 9 lbs. per head daily of cane molasses were fed to mules in Louisiana tests to replace much of the grain.[103] However, such a heavy allowance tended to increase sweating and "winding" in hot weather. When fed as a partial substitute for grain, molasses was about equal to corn in value per pound. Mules fed only molasses and chopped hay, without grain, were not able to do heavy work in hot weather.

Beet molasses can likewise be used for horses and mules, but it should not be fed in excess because of its very laxative nature. In trials with 130 hard-worked horses of a Budapest transportation company, good results were obtained with a ration, per 1,000 lbs. live weight, of 4.1 lbs. beet molasses mixed with 5.6 lbs. wheat bran and fed with 5.7 lbs. corn and an unlimited allowance of hay.[104] One pound of molasses replaced 0.78 lb. of corn.

936. Molasses for swine.—Molasses, either cane or beet, is used much less commonly for swine than for cattle, sheep, or horses. However, when considerably cheaper than corn or other grain, it can be substituted for a part of the grain. A small percentage of molasses is often included in formula, or mixed, commercial supplements and other formula swine feeds as a binder, to prevent waste in feeding.

Too much molasses causes scours in young pigs. However, in Hawaiian tests as much as 20 per cent of cane molasses was satisfactory for pigs from weaning up to 70 lbs. in weight, if it was introduced gradually into the feed mixture.[105] Thus fed, the value of the molasses per pound was about two-thirds that of grain, and molasses was economical in Hawaii, where it is very cheap.

For older pigs molasses can form a larger proportion of the ration. However, the rate of gain is usually less on rations containing 10 per cent or more of molasses than on rations without molasses. In several experiments in which 10 to 20 per cent or more of molasses has been added to good rations for well-grown pigs, the results have varied widely.[106] In some tests molasses has been worth from 70 to 84 per cent as much as grain, but in more of the experiments it has had an exceedingly low value. It is not therefore wise to include any appreciable amount of cane molasses in swine rations unless its cost is far below that of grain.

Beet molasses is apt to cause scours in pigs unless they are started on it very gradually and only limited amounts are fed. In Utah experiments adding as little as 15 per cent of beet molasses to the ration of young pigs produced a serious nutritional disease.[107] The pigs not only failed to grow but had a staggering gait and often died. Supplementing such a ration with green alfalfa or with 5 per cent of brewers' dried yeast prevented the trouble. Hogs weighing 100 lbs. or more at the start were fed as much as 40 per cent of beet molasses without injury, even without these supplements.

937. Molasses for poultry.—Molasses is not commonly used for poultry, but 2 to 5 per cent of cane molasses is often included in formula, or mixed, poultry mashes. Too much molasses in a poultry ration makes it too laxative. The best results are usually secured with not over 2.5 per cent of molasses, though 5 or 6 per cent is sometimes used in an all-mash ration, or 10 per cent in a mash fed with scratch grain.[108]

In trials in Hawaii, where cane molasses is very cheap, as much as 33 per cent of molasses was economical in rations for chicks, 18 per cent for cockerels, and 35 per cent of a mixture of 5 parts molasses and 1 part sugar cane bagasse pith for layers, although the feed efficiency was lowered considerably with so much molasses.[109]

938. Molasses feeds; alfalfa-molasses feeds.—Cane molasses or beet molasses is used as an ingredient in many of the formula feeds, or commercial mixed feeds, on the market, especially those for dairy cattle, beef cattle, and horses. Molasses is added to high-grade mixed feeds on account of its palatability, because it prevents dustiness, and also because it is often one of the cheapest sources of readily digested carbohydrates. Many experienced dairymen prefer a high-grade mixture containing molasses to one made of the same ingredients, except without molasses.

In lower-grade mixed feeds, molasses has a special value, as it aids in making a mixture palatable that might otherwise not be liked by stock. Unfortunately, molasses also tends to mask the presence of low-grade ingredients, and therefore may make a trashy feed appear much more valuable than it really is. From the list of guaranteed ingredients and the guarantees for protein, fat, and fiber, one can usually determine approximately the relative value of any particular mixed feed.

In several experiments at corn-belt stations with fattening cattle, rations including various brands of commercial molasses feeds have been compared with such standard rations as corn grain, corn silage, legume hay, and a small amount of linseed meal or cottonseed meal.[110] In nearly all of these tests the gain was lower instead of higher on the molasses feed, and the profit was less than on the standard rations. These trials show that in the commercial fattening of cattle in the corn belt, corn grain must commonly be used as largely as possible, in order to secure the greatest net returns.

In a Michigan test with fattening cattle, two brands of commercial molasses feeds consisting chiefly of cane molasses, crushed oats, cracked corn, and alfalfa meal, had no appreciable advantage over a mixture of crushed oats and cracked corn, and the latter was cheaper.[111] The molasses feeds sometimes became sour or caked in the sacks.

In the western alfalfa districts a considerable amount of *alfalfa-molasses feeds* is manufactured. These consist of combinations of alfalfa meal with various percentages of beet or cane molasses. Usually such feeds contain 20 to 40 per cent of molasses.

Alfalfa-molasses feeds are palatable to stock and can be used to replace a limited amount of the grain in the ration of dairy cows, beef cattle, and sheep. It must be borne in mind, however, that such feeds are more like a roughage than like a concentrate. Therefore, when any considerable amount is fed to fattening cattle or sheep, the value of the alfalfa-molasses feed is much below that of grain, and not greatly different from that of alfalfa hay.[112] Sometimes alfalfa-molasses feeds are unwisely used as a substitute for such protein supplements as linseed meal or cottonseed meal. They are not high in protein, and therefore should be used as a substitute for part of the grain, and not as a protein supplement.

Molassine meal, sometimes made in Europe by mixing molasses with peat or sphagnum moss, has occasionally been imported into the United States. Peat has no nutritive value and the moss is also of very low worth, though arctic animals live on it to some extent. Practically the only nutrients in molassine meal are in the molasses, and at the prices usually

asked it has been a very uneconomical purchase.[113]

939. Dried molasses mixtures.—Molasses can be dried to form a dry meal, but such a product absorbs so much moisture on exposure to the air that it soon becomes sticky. It must therefore be shipped in moisture-proof bags, and speedily mixed with other ingredients.

Various dry mixtures of molasses and absorbent feeds, such as ground light-weight grain screenings, brewers' dried grains, or corn oil meal, are marketed, which are free-flowing and do not cake. Some such products apparently have a much lower percentage of molasses equivalent than is indicated by the claims made for them, judging by the fiber content. Others may have the equivalent of 45 per cent or more of molasses.

The actual economy of such products can be estimated from the guaranteed composition and ingredients, especially from the fiber guarantee.

940. Condensed beet solubles product.—This feed, also called MC 47, is the condensed residue obtained in the separation of glutamic acid from beet molasses or the Steffen's filtrate in beet sugar production. It has about 64 per cent dry matter, 20 per cent crude protein, and 18 per cent mineral matter. It is very high in betaine, which can partially replace choline in the diet, and is therefore useful in certain poultry rations.[114] (218)

In California experiments it furnished 80 per cent as much digestible nutrients as average cane molasses.[115] A concentrate mixture or ground hay with 10 per cent of this product added was readily eaten by dairy cows after the second feeding of the mixture, and mixtures containing it were satisfactory for steers or lambs.

941. Sugar.—Though the nutritive value of sugar is no greater than that of an equal weight of starch, the great fondness for it shown by stock makes it helpful in some cases for stimulating the appetite. For this reason, a small amount is sometimes added to concentrate mixtures used in fitting animals for show. Also, as shown in Chapter XXXV, the consumption of pig starters or mixtures for creep-feeding suckling pigs may be increased by including 5 to 20 per cent of cane sugar in the mixture.

Experiments were conducted by the Hawaiian Station to find to what extent low-grade sugar could be substituted for imported grain in poultry rations, if imports were cut off at any time.[116] Because of the sticky nature of this sugar, which contains considerable molasses, it was usually mixed with 10 to 20 per cent of ground sugar-cane bagasse pith. The results were satisfactory when such a mixture formed as much as 35 per cent of the ration for hens and 40 per cent for chicks, the protein content being adjusted properly.

In another Hawaiian trial the addition of 5 per cent of cane sugar to a ration for pigs increased the feed consumption and produced slightly more rapid gains.[117] In a Kansas test there was no advantage in adding 0.5 lb. of sugar per head daily to a ration for horses.[118]

In a recent Utah experiment the feeding of cane sugar to beef cattle and pigs for about 3 days before slaughter tended to improve slightly the dressing percentage and also the flavor of the livers.[119]

942. Dried beet pulp; dried molasses-beet pulp.—Most of the beet pulp produced in this country is dried at the beet-sugar factories to form *dried beet pulp*, or is combined with molasses and dried to form *dried molasses-beet pulp*. These feeds are palatable, bulky, slightly laxative, and keep well in storage.

Dried beet pulp and dried molasses-beet pulp are rich in carbohydrates, but they are relatively low in protein and poor in fat. Dried beet pulp has an average of 8.8 per cent protein, 0.6 per cent fat, 19.6 per cent fiber, and 58.7 per cent nitrogen-free extract. Though it is high in fiber for a concentrate, the fiber is well digested, and dried beet pulp has 68.7 per cent of total digestible nutrients, which is nearly as much as in oats.

Dried molasses-beet pulp is slightly higher in protein and nitrogen-free extract and somewhat lower in fiber than is dried beet pulp. However its feeding value is approximately the same.

Both dried beet pulp and dried molasses-beet pulp have a fair amount of calcium, but they are very low in phosphorus. When a considerable amount of either of these feeds is used, it may therefore be necessary to add a phosphorus supplement to the ration.

Dried beet pulp is fair in niacin content, but is low in other B-complex vitamins. It does not supply carotene or vitamin D.

Largely because of the bulky nature and the palatability, dried beet pulp and dried molasses-beet pulp are very popular feeds for dairy cattle, and most of the supply is used for this purpose. These feeds are also used extensively in the sugar-beet districts as a substitute for part of the grain in fattening cattle or sheep and may replace part of the grain for horses.

By rolling dried molasses-beet pulp through corrugated rollers, the bulk can be reduced and the feed can be mixed more readily with grain. Molasses-beet pulp pellets are also made, which weigh about 4 times as much per bushel as ordinary dried molasses-beet pulp. These eliminate loss from blowing when fed in the open.

943. Dried beet pulp; dried molasses-beet pulp for dairy cattle.—As a source of nutrients for economical milk production, these bulky, palatable feeds are worth no more than ground corn or oats, or even less.[120] However, as a part of the concentrates for cows on official test, or when a limited amount is added to a heavy concentrate mixture to supply bulk, they may be worth more than grain. Cows on official test are often fed 6 to 10 lbs. of dried beet pulp per head daily, well soaked from one feeding to the next with water to which molasses is sometimes added.

When silage or other succulent feed is not available, dried beet pulp, soaked before feeding, is occasionally used as a substitute, though it is usually more expensive than silage.[121] If cows are provided with water in drinking cups, the results are probably just as good when dried beet pulp, up to an allowance of 8 lbs. per cow daily, is fed dry as when it is soaked.[122]

Both dried beet pulp and dried molasses-beet pulp are too bulky and too low in digestible nutrients to be very efficient as the only concentrate for good dairy cows. They have a considerably higher value when mixed with more concentrated feeds.[123]

944. Dried beet pulp; dried molasses-beet pulp for other stock.—When cheaper per ton than grain, these feeds are economical substitutes for not over one-half the grain in rations for fattening cattle or lambs. Thus used, they produce good gains and have a high feeding value. Adding these bulky feeds to a fattening ration helps to keep the animals on full feed without digestive disturbances, and tends to reduce trouble from bloat on such a ration as ground barley and alfalfa hay.

In results of experiment station trials compiled by the author, these feeds have, on the average, been about equal to barley or grain sorghum in value per ton, when replacing not more than one-half the grain in rations for fattening cattle or lambs.[124] Maynard of the Great Western Sugar Co. states that in 46 experiment station trials with fattening cattle or lambs, a ton of dried molasses-beet pulp replaced an average of 1,782 lbs. grain and 836 lbs. alfalfa hay.[125] Harris of the Holly Sugar Corporation, from a study of 51 trials by experiment stations and beet sugar companies, has computed that dried molasses-beet pulp has a net-energy value higher than corn grain, when fed as a substitute for part of the grain in rations for fattening cattle or lambs.[126]

These beet by-products even give fair to good results as the only concentrate for fattening lambs, when fed with alfalfa hay. Thus fed in 18 trials, dried molasses-beet pulp was worth about 80 per cent as much as corn.[127] Dried beet pulp or dried molasses-beet pulp can also be used as a substitute for grain in wintering breeding ewes or beef cattle.[128]

Dried beet pulp is not well liked by horses, but when mixed with other concentrates it is satisfactory when forming not over one-third of the concentrate allowance.

These beet by-products are too bulky to have much usefulness for swine or poultry.[129] However, in English tests pigs weighing 60 lbs. or over made fair gains when dried beet pulp or molasses-beet pulp replaced part of the grain in the ration.[130]

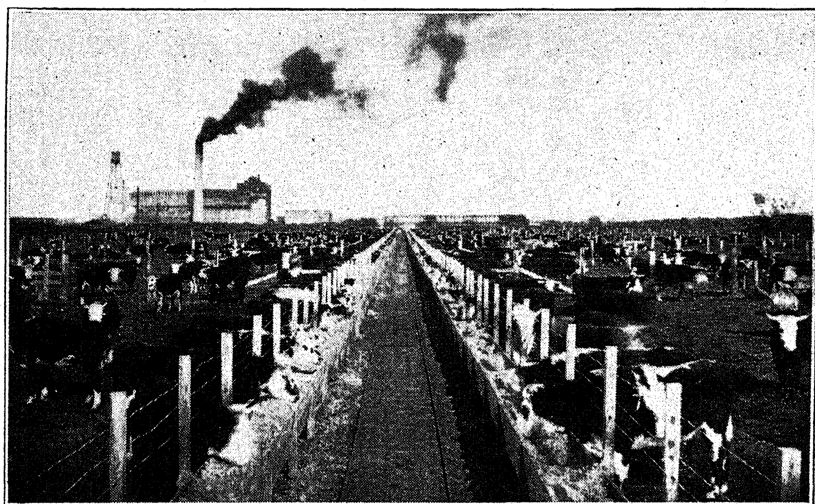
945. Wet beet pulp.—The wet pulp that is not dried to make dried beet pulp is usually stored at the beet-sugar factories

in huge open silos, which are merely paved areas with strong walls. Here the pulp undergoes an acid fermentation similar to that which occurs in corn silage. It is then hauled to the farms where it is fed, at intervals frequent enough to prevent spoilage. Sometimes the fresh pulp is hauled to the farms and stored in ordinary silos or else in trench or pit silos.

Ensiled pulp keeps much better than fresh pulp when exposed to the air, and it is therefore preferred for feeding. Owing both to the draining away of water and to the loss of nutrients in the fermentation, there will be a shrinkage in weight of about 30 per cent when the pulp is ensiled in a trench silo.[131]

Wet beet pulp is very watery and contains an average of only 11.6 per cent dry matter. Even pulp that has been pressed at the factory to remove some of the water has only about 14 per cent dry matter. The chief value of wet beet pulp is in the carbohydrates it contains. Though most of the sugar has been extracted, the fiber and nitrogen-free extract of wet beet pulp are well digested by cattle and sheep. The dry matter in wet beet pulp is about equal to that of roots in feeding value.

Beet pulp is low in protein and especially low in phosphorus. When heavy allowances of pulp are fed, these deficiencies must be corrected. In the West wet beet pulp is generally fed with alfalfa hay, which largely or entirely makes good the lack of protein and is usually fair in phosphorus content. However, Utah experiments show that dairy cows or fattening stock may suffer seriously from phosphorus deficiency when fed rations made up largely of wet beet pulp and alfalfa hay without a phosphorus supplement.[132] To guard against a lack of phosphorus, steamed bone meal or some other safe phosphorus supplement should therefore be added to such rations. When a phosphorus-rich protein supplement is fed, such as cottonseed meal, linseed meal, or wheat bran, it may supply enough of this mineral.



Fattening Steers on Beet Pulp in the West

In the vicinity of the beet sugar factories thousands of cattle are fattened on wet beet pulp and other feeds. In the feed lots shown in this view the beet pulp is brought from the beet sugar factory on the tramway.

Wet beet pulp is fed chiefly to fattening cattle or lambs or to dairy cattle. In limited amounts it is satisfactory for idle horses and can even be fed to swine as a substitute for a part of the grain.[133]

Stock should be accustomed to the pulp gradually, but later cattle and sheep may be allowed all they will clean up, if there is a plentiful supply.

946. Wet beet pulp for dairy cows.—Wet beet pulp is liked by dairy cows and produces milk of good quality when fed under proper conditions and not in excess. In Utah trials cows fed wet beet pulp as a substitute for corn silage produced fully as much milk as those fed corn silage.[134]

Because of the much lower dry matter content of wet beet pulp, it required 2.1 lbs. of it to replace 1 lb. of corn silage. Per pound of dry matter, the pulp was worth slightly more than corn silage. To avoid any danger of injuring the flavor of the milk, wet beet pulp should be fed after milking and in a sanitary manner, the same as in the case of silage.

947. Wet beet pulp for beef cattle and sheep.—In the vicinity of the western beet-sugar factories large numbers of cattle and sheep are fattened on wet beet pulp. This is usually fed with alfalfa hay, which makes good the low protein content of the pulp. If a liberal amount of alfalfa hay is not supplied, a sufficient amount of protein supplement should be fed to balance the ration.

Often cattle are fed only wet beet pulp and alfalfa hay for the first part of the fattening period and then a limited amount of grain or other concentrates is added during the latter part. Sometimes cattle are fattened on only wet beet pulp and alfalfa hay, but the gains are much slower than when a limited amount of concentrates is fed, and also the cattle do not reach as good a finish.

When beet pulp and beet molasses form a large part of the rations, a deficiency of phosphorus must be guarded against. The importance of this is shown in 3 Utah experiments in which steers gained only 1.07 lbs. per head daily on the average when fed only wet beet pulp, beet molasses, and all the alfalfa hay they would eat.[135] Adding 0.1 lb. of bone meal daily to this ration doubled the gains and reduced the feed cost per 100 lbs. gain by 44 per cent.

When a sufficient amount of wet beet pulp is available, fattening cattle are often fed 60 lbs. or more per head daily and fattening lambs 5 lbs. or more.[125] When wet beet pulp is fed along with grain and hay, 100 lbs. of dry matter in the pulp have a higher value than the same amount of dry matter in dried beet pulp.

In 4 Colorado trials with fattening calves the addition of wet beet pulp to a ration of ground barley, alfalfa hay, and 1.0 lb. cottonseed cake slightly increased the rate of gain.[136] Each ton of wet beet pulp was equal to 145 lbs. of concentrates and 342 lbs. of alfalfa hay, without considering the more rapid gain and slightly better finish of the cattle. In 2 Oregon trials, the gain of fattening yearlings was increased by adding wet beet pulp to a ration of corn and alfalfa hay, but each ton of beet pulp saved only 36 lbs. corn plus 382 lbs. hay.[137]

In 32 similar experiments with fattening lambs, the addition of wet beet pulp to a ration of grain and alfalfa hay has likewise usually increased the gains slightly.[138] In these experiments 1 ton of wet beet pulp replaced 129 lbs. of grain plus 376 lbs. of hay. Wet beet pulp is especially suitable for fattening aged ewes with poor teeth. In feeding heavy allowances of the watery pulp, it is important that the yards be kept dry by proper drainage and the use of bedding.

Because of the low content of dry matter, it usually requires nearly 2 tons of wet beet pulp to replace a ton of corn silage for fattening cattle or sheep. In 9 experiments with fattening cattle the gain has been a little more rapid on a ration of wet beet pulp, alfalfa hay, and concentrates than when corn silage replaced the pulp.[139] Each ton of siloed wet beet pulp replaced 1,017 lbs. silage, plus 24 lbs. concentrates and 13 lbs. hay.

IV. Distillery and Fermentation By-products

948. Distillery by-products.—In the manufacture of distilled liquors and alcohol from grain, the grain is first ground and cooked with water. Then after cooling, malt is added, to furnish amylase, or diastase, the starch-digesting enzyme, or else an amylase-containing product produced by fermentation, called "fungal amylase," is added.

The mixture, called mash, is held at the proper temperature for the amylase to change the starch into sugar. In the next stage of the process the sugar in the watery mash is converted into alcohol by the action of yeast. After the fermentation is completed, the alcohol is distilled off, leaving a watery residue, called *stillage,* or *distillery slop.*

The coarser particles are usually strained out of the stillage, forming *wet distillers grains.* The water-soluble material and the fine particles that pass through form what is known as thin stillage, or thin slop. This may be condensed by evaporation and dried to form *dried distillers solubles.* Sometimes the distillers solubles are marketed in condensed, or semi-solid, form.

The condensed distillers solubles are often added to the wet distillers grains and the mixture then dried, to form *distillers dried grains with solubles,* also called *dark distillers dried grains.* Some-

times the wet distillers grains are dried without adding the distillers solubles. This product is called *distillers dried grains without solubles,* or *light distillers grains.*

949. Distillers dried grains.—Distillers dried grains made from a grain mixture in which corn predominates are called *corn distillers dried grains.* They are high in protein, averaging 26 per cent or more and are also rich in fat, with an average well over 8 per cent. Though they are almost as bulky as wheat bran, they are highly digestible and are as rich as corn grain in total digestible nutrients. *Corn distillers grains without solubles* have 84.0 per cent of total digestible nutrients, on the average.

The chief difference between distillers grains with solubles and the grains without solubles is that the former are very much higher in B-complex vitamins. This higher vitamin content increases their value in poultry rations but is probably not important for cattle or sheep under usual conditions. Distillers grains with solubles are also higher in minerals than the grains without solubles.

Rye distillers dried grains, made from a grain mixture in which rye predominates, are lower in protein than the average for the corn grains. Formerly, the average protein content was only 18.5 per cent and the average fiber content was 15.6 per cent. The value of such rye distillers grains was much lower than of corn distillers grains. Some recent samples of rye distillers dried grains have had an average of 24.4 per cent protein and only 11.5 per cent fiber. Such rye distillers grains more closely approach corn distillers grains in value.

Some grain sorghum and wheat have also been used in the production of alcohol or distilled liquors. *Sorghum distillers dried grains* of high grade, made from a grain mixture in which grain sorghum predominates, resemble corn distillers grain in composition, except that they are lower in fat. Some sorghum distillers grains have been lower in protein and higher in fiber.

During World War II considerable wheat was used in this country in producing alcohol for technical purposes. The *wheat distillers dried grains* which are made when entire wheat grain is processed have about as much protein as do corn distillers grains. When wheat grits are employed, from which most of the bran has been removed, the wheat distillers grains may have 46 per cent protein.

Distillers dried grains made by the fungal-amylase process are about equal to those made by the malt process.[140]

Distillers dried grains are used chiefly for dairy cattle but are also a satisfactory protein supplement for beef cattle or sheep. They have decided limitations as a feed for swine or poultry. Distillers grains are not especially well liked by stock when fed alone, but there is no difficulty when they are used in suitable mixtures.

Occasionally, distillers dried grains are cheaper than corn or other cereal grains. They may then be used as a substitute for part of the grain in feeding dairy cattle, beef cattle, sheep, or horses. They had best form not more than about half of the concentrate mixture for cattle or sheep and not more than one-fourth of the concentrates for horses.

Because of the considerable range in composition of various types of distillers dried grains, they should be bought on a definite guarantee of composition. Some of the distillers dried grains sold as corn distillers grains have not been up to the usual grade for this feed, apparently being made from a mixture containing a large proportion of other grain.

950. Distillers dried grains for dairy cattle.—Corn distillers dried grains are a popular protein supplement for dairy cows and are a favorite ingredient in concentrate mixtures for cows on official test. Because of the high fat content of corn distillers grains, they are especially valuable for milk production when the other feeds in the ration are rather low in fat. (**1020**)

In New York experiments corn distillers grains have been slightly superior to a mixture of corn gluten feed and soybean oil meal for dairy cows, and rye distillers grains having 25 per cent pro-

tein were about equal to corn gluten feed.[141] Sorghum distillers grains with 30 per cent protein also equaled corn distillers grains.

951. Distillers grains for beef cattle.—Distillers dried grains are a satisfactory protein supplement for beef cattle. Because of their lower protein content, it will take about 1.5 lbs. to furnish as much protein as in 1.0 lb. of soybean oil meal or cottonseed meal, but this amount of distillers grains will supply more total digestible nutrients.[142] Corn distillers dried grains have about as much protein and total digestible nutrients as a mixture of half soybean oil meal and half grain or corn-and-cob meal. They were equal to such a mixture in Ohio trials with beef calves being wintered and in a Kentucky trial with beef cows nursing calves in winter.[143] When used as the only protein supplement in rations for fattening cattle, distillers grains may not produce quite as rapid gains as soybean oil meal, linseed meal, or cottonseed meal.

In 3 Kansas tests 4 lbs. of corn distillers grains were worth somewhat more than 2 lbs. cottonseed cake to supplement sorghum grain and sorghum silage for fattening steers.[144] In Kentucky experiments with fattening cattle a mixture of half corn distillers grains and half soybean oil meal produced slightly more rapid gains, on the average, than distillers grains as the only supplement.[145] Replacing half the distillers grains with urea plus sulfur reduced the gains. In Kansas trials corn distillers grains were very slightly superior to sorghum distillers grains for fattening cattle.[144]

Used as a substitute for one-third the corn for fattening cattle in Maryland trials, rye distillers grains were worth 73 per cent as much as No. 2 grade corn.[146]

952. Distillers dried grains for sheep.—Corn distillers grains with solubles produced nearly as good results as did linseed meal as the protein supplement for fattening lambs in 4 New York experiments.[147] Because of the lower protein content of distillers grains, somewhat more was needed to balance the ration, and the distillers grains were worth 91 per cent as much per ton as linseed meal. In one trial corn distillers grains without solubles had a lower value, perhaps due to the use of a considerable proportion of other grains in the manufacture. As a substitute for part of the corn grain, distillers grains were worth slightly more per ton than corn when they replaced one-third the corn, and 100 lbs. were equal to 95 lbs. corn minus 11 lbs. hay when they replaced half the corn.

Rye distillers dried grains were not satisfactory as the only concentrate for wintering breeding ewes in Maryland trials.[148] Death losses and nervous disorders occurred, apparently because of some nutritive deficiency.

953. Distillers grains for swine.—Distillers dried grains are not usually fed to swine, since they are much better suited for feeding cattle, especially dairy cows.[149] They are unsatisfactory as the only protein supplement for pigs not on pasture. Distillers grains produce fair results when replacing not over one-half the tankage or meat scrap in a ration, or when used as the protein supplement for pigs on good pasture. In an Ohio test corn distillers dried grains had a low value when used as a substitute for one-fourth of the corn in a well-balanced ration for pigs not on pasture.[150]

954. Distillers grains for poultry.—Distillers dried grains can be used satisfactorily in rations for poultry, if there is a sufficient amount of such a protein supplement as dried skimmilk, fish meal, or meat scrap, which have protein of better quality.[151] Because of the bulkiness of distillers dried grains, rations for laying hens had best not have more than 10 per cent of distillers grains, and rations for chicks not over 7 or 8 per cent. For poultry, distillers grains with solubles are decidedly preferable to grains without solubles, unless an abundance of riboflavin and other B-complex vitamins is supplied by other feeds.

When corn distillers dried grains are much cheaper than corn, they may

be an economical substitute for one-half of the corn in an all-mash laying ration.[152]

955. Distillers dried solubles.—Distillers dried solubles are used chiefly in formula, or mixed, feeds for poultry, swine, and dairy calves, because of their high content of certain B-complex vitamins. However, the dried solubles may have fully as much protein as do corn distillers dried grains, and they are a satisfactory protein supplement for dairy cows, beef cattle, and sheep.

The protein of distillers solubles is not of high quality for poultry and swine and does not effectively supplement the protein of the cereal grains.[153] Distillers solubles are very rich in niacin and choline and have a good content of riboflavin, pantothenic acid, and thiamin, but they do not have much vitamin B_{12}. They also supply one or more of the unidentified vitamins important in poultry rations.[154]

Molasses distillers dried solubles contain much less protein than the solubles from grain fermentation, having an average of only 12.9 per cent. They have over 24 per cent mineral matter, and hence furnish much less total digestible nutrients than the grain solubles.

Because of the content of B-complex vitamins, 2.5 to 5.0 per cent of distillers solubles is included in many formula poultry feeds. The addition of distillers solubles to a practical ration containing little or no animal protein supplements appreciably increases the rate of growth and the feed efficiency.[155] Not more than 5 to 10 per cent of distillers solubles should generally be used in poultry rations, because of the laxative effect.

For swine, distillers solubles have a distinct value as a source of B-complex vitamins when added to dry-lot rations low in these vitamins. Catron of the Iowa Station has recently summarized the results of 21 experiment station trials in which distillers solubles have been added to various types of rations for growing and fattening pigs, with and without an animal protein supplement.[156] On the average, the addition of distillers solubles increased the daily gain 4.2 per cent and reduced the amount of feed per 100 lbs. gain 3.3 per cent. In 9 of the trials distillers solubles did not increase the gains.

The benefit from adding distillers solubles to such a ration as corn, soybean oil meal, 4 per cent alfalfa meal, and minerals for growing and fattening pigs is shown by 4 Ohio trials.[157] The pigs remained healthier, the daily gain was increased 0.24 lb., and 12 lbs. less feed were required per 100 lbs. gain. Adding distillers solubles to the ration produced about as good results as adding meat scrap.

In Illinois experiments with brood sows and pigs kept continuously in dry lot, without pasture or any green feed, there was a benefit from adding 6 per cent of distillers dried solubles to typical rations that contained no alfalfa meal or not over 5 per cent of alfalfa.[158] Increasing the alfalfa to 15 per cent produced similar improvement.

Wisconsin tests indicate that the addition of extra alfalfa to swine rations fed under restricted dry-lot rations generally produces as good results as adding distillers solubles, and at lower cost.[159] Kentucky and Nebraska experiments show that distillers solubles are not satisfactory as the only protein supplement for pigs, but that they can be used as a substitute for linseed meal or soybean oil meal in trio-type supplemental mixtures.[160]

Distillers dried solubles may be used in dry calf starters or milk replacers as a source of B-complex vitamins. Corn or sorghum distillers solubles have been a satisfactory substitute for dried skimmilk or dried whey and also dried yeast in calf starters where the chief protein supplement was soybean oil meal, which provides excellent protein.[161] There is no advantage in adding distillers solubles to a calf starter that otherwise has ample B-complex vitamins.

Dried distillers solubles are a satisfactory protein supplement for dairy cows or beef cattle, but they do not have the especial value as a source of B-complex vitamins that they have for poultry, pigs, or young dairy calves. In New York trials corn distillers solubles were slightly

superior to corn gluten feed as a protein supplement for dairy cows, but not quite equal to corn distillers dried grains.[162]

In 2 Kentucky trials fattening steers fed corn distillers solubles high in protein as the supplement gained more rapidly than steers fed soybean oil meal as the protein supplement, and they required 7 per cent less feed per 100 lbs. gain.[163] In another trial corn distillers solubles having only 20 per cent protein were much less valuable. Corn distillers solubles were very satisfactory as the protein supplement for wintering stocker steers.

956. Stillage, or distillery slop.—The stillage, or distillery slop, left after the alcohol is distilled from the fermented mash, is sometimes fed to livestock on farms near a distillery. The whole stillage has only 6 to 8 per cent dry matter, and the strained stillage, after the wet distillers grains are removed, about 4 per cent or less.

Stillage has been chiefly used for fattening cattle, which are allowed to drink all of it that they will take. To produce satisfactory results the cattle should also be fed at least 5 lbs. per head daily of hay of reasonably good quality, that will supply considerable vitamin A value. If the stillage comes from grain other than yellow corn, there may be a serious deficiency of vitamin A, unless the hay is of good quality or a vitamin A supplement is fed. It is wise to supply a mineral mixture to furnish additional calcium.

Cattle will make fair gains—as much as 1.5 to 1.9 lbs. per head daily—when fed no grain in addition to stillage and a limited amount of hay. To increase the gains and improve the finish, a small amount of grain is often fed. No protein supplement is needed. The stillage sometimes has an unduly laxative effect. In such cases roughage should be fed that will counteract the effect, such as grass hay, straw, or cottonseed hulls.

In a Kentucky trial yearling cattle full-fed on stillage with 5 lbs. of hay a day consumed an average of 20.6 gallons, or about 175 lbs., per head daily and gained 1.55 lbs. a day.[164] Per pound of gain, 113 lbs. of stillage and 3 lbs. of hay were required. It was estimated that 13.4 lbs. of total digestible nutrients were required per pound of gain, which is considerably more than needed when cattle are fattened on a ration with a liberal amount of grain.

In a Maryland test, rye stillage containing 5 per cent dry matter satisfactorily replaced one-half the concentrates for dairy cows.[165] Thus fed, the stillage was worth 5 per cent as much per ton as the concentrate mixture. To get some of the cows to consume a large amount of stillage, it was necessary to warm it and add a little molasses.

Strained or thin stillage proved too watery for use in swine feeding in Kentucky tests.[166] Heavy feeding of distillers stillage tends to produce soft pork.

In another Kentucky test whole stillage containing 8 to 9 per cent dry matter was used satisfactorily to replace a considerable part of the corn in a growing mash for chickens.[167]

957. Yeast.—The most common kind of yeast used in stock feeding is *brewers' dried yeast,* made from the yeast filtered from beer or ale after the fermentation is completed. This yeast is of the *Saccharomyces* type. Dried yeast of the *Torula* type is now made in this country by the fermentation of the waste sulfite liquor from making paper pulp. Yeast for feeding can also be produced in the fermentation of molasses for alcohol.

The chief use of *brewers' dried yeast* in stock feeding is as a vitamin B-complex supplement, especially for poultry. It is very rich in all the B vitamins, except that it has very little vitamin B_{12}. It also supplies two of the unidentified vitamins important for poultry.

Brewers' dried yeast has an average of 44.9 per cent protein, and is high in phosphorus, containing 1.56 per cent. In drying the yeast, it is commonly heated sufficiently to kill the yeast cells and destroy the fermenting power. Otherwise, too great fermentation might be produced in the digestive tract, causing indigestion.

It is shown in Chapter VII and in the chapters of Part III that there is generally no advantage in adding yeast as a vitamin supplement to livestock rations that already supply sufficient amounts of the B-complex vitamins. (210) The use of irradiated yeast as a vitamin D supplement is discussed in Chapter VII. (203)

Yeast may sometimes have a special value to restore the appetite of animals that are badly run down. In the case of animals which are very debilitated because of heavy infection with internal parasites, treatment with an anthelmintic to remove the parasites is often fatal. Drenching the animal with a yeast suspension and then feeding yeast for a few days tends to restore the appetite and build the animal up so it can stand the treatment for removal of parasites.[168]

If the price of brewers' dried yeast or other dried yeast is such that it is an economical source of protein, it can be used in place of other protein supplements in stock feeding. In Canadian experiments brewers' dried yeast equaled linseed meal for dairy cows.[169] In Hawaiian trials dried yeast, fed as 25 to 35 per cent of the concentrate mixture for dairy cows, gave nearly as good results as soybean oil meal.[170]

Though the protein in dried yeast helps to supplement the protein of the cereal grains, dried yeast is not satisfactory as the only protein supplement for swine or poultry. It gives satisfactory results when used in combination with supplements that provide protein of better quality.[171] In English experiments dried yeast tended to produce rickets in pigs when forming 20 per cent of the ration, unless an abundance of calcium was supplied and also of vitamin D.[172]

Dried torula yeast, or wood yeast, produced from sulfite waste liquor, resembles brewers' dried yeast in composition and may be used similarly. Torula yeast is apparently lower in methionine than brewers' yeast, and should be used with feeds that supply an ample amount.[173] It also has considerable nonprotein nitrogen, which cannot be utilized by poultry or swine.[174]

Dried torula yeast satisfactorily replaced soybean oil meal as the protein supplement in New Hampshire tests with dairy cows and laying hens.[175] A combination of torula yeast and soybean oil meal was a satisfactory protein supplement for chicks, but the growth was reduced when the yeast was the only protein supplement.

958. Other fermentation by-products.—Other dried or condensed by-products are produced from the residue that remains when alcohol is made from molasses, or when molasses or grain is fermented in special processes to make acetone, butyl alcohol, and other products. These by-products are used chiefly in poultry rations as vitamin supplements to supply riboflavin and other B-complex vitamins, and also certain unidentified vitamins or factors. (221) They are sold under various trade names, with guaranteed content of riboflavin.

Yeast dried grains and *vinegar dried grains* are by-products in the manufacture of yeast and of malt vinegar from grain and other materials. They resemble rye distillers dried grains in composition.

V. Formula Feeds, or Commercial Mixed Feeds; Mineral and Vitamin Mixtures; Premixes

959. Formula feeds.—The manufacture of formula feeds (commercial mixed feeds) has become a very important industry in the United States. It is estimated that 33 million tons of formula feeds are made annually in this country, with a value of well over two billion dollars. About 6,000 feed manufacturers produce formula feeds under their own brands, and a much greater number of feed stores make mixed feeds for their customers.

About 60 per cent of the tonnage of formula feeds is made for poultry, about 19 per cent for dairy cattle, 11 per cent for swine, and smaller amounts for beef cattle and sheep, which are fed chiefly home-grown grains.[176] In the intensive dairy districts of the Northeastern and North Atlantic States by far the greater part of the concentrates fed dairy cows are formula feeds, and large-scale poultrymen use chiefly formula feeds.

Most of the formula feeds on the market are intelligently and honestly made of good ingredients, and such feeds produce very satisfactory results. In purchasing formula feeds one should consider the general reputation of the manufacturers of the various brands of feed available. He should also find from the feeding stuff inspection reports of his state whether any particular manufac-

turer has in the past been fully meeting his guarantees of composition and of declared ingredients.

In the opinion of the author there is no one best formula for a feed mixture for any class of stock, in spite of claims sometimes made to the contrary. Many formulas can be recommended that will produce excellent results, and the choice among them will depend primarily on the prices of the various individual ingredients at any particular time.

It has been emphasized in Chapter XII that it is decidedly uneconomical to adhere to the same formula, month after month and year after year, without regard to the relative cost of the various individual ingredients that are available. Feed manufacturers can obviously study the changes in the prices of various feeds much more closely than most farmers. They are therefore in a position to make such changes in their formulas as are necessary to furnish efficient mixed feeds to their customers at the minimum price.

Manufacturers of formula feeds who have chemical laboratories or who have chemical service available can control the vitamin content of such feeds as poultry mashes. This is difficult when they are made on the farm.

Suitable concentrate mixtures and complete rations are recommended in Part III and in Appendix Table VII for each class of stock. It is believed that these mixtures and rations will all produce excellent results, when made of good-quality feeds, and fed intelligently. It is hoped that these recommendations may be helpful both to farmers and to those manufacturing mixed feeds.

In deciding whether to buy a commercial mixed feed or to mix a suitable feed himself, one should base his decision on the cost of the mixed feed and the cost of the home mixture, including the labor for the mixing. Convenience must also be considered. Unless a manufactured vitamin and mineral premix is used, it is difficult to mix on the farm such complicated formulas as are now commonly used for poultry mashes, pig starters, and milk replacers for dairy calves. This is because of the very small quantities of certain vitamin and mineral supplements usually included in such formulas.

Often a high-grade mixed feed can be bought at a price little or no higher than it would cost to mix a feed of the same value on the farm. The wise manufacturer secures his profits by building up a large volume of sales through selling his feed on a narrow margin of profit. He uses his ability to purchase ingredients in large quantities and his knowledge of the prices and values of various ingredients to make mixed feeds that furnish nutrients most economically.

Especially in using molasses, the feed manufacturer has a great advantage over the individual farmer. When bought by the feed manufacturer in tank cars, molasses is often the cheapest source of carbohydrates in many parts of the country. Yet, when purchased by a farmer in barrels, molasses may be more expensive than grain.

960. Importance of keeping safely within the guarantee.—It is exceedingly important for the permanent success of any feed manufacturer that his feeds at all times conform strictly to the guarantees of chemical composition and ingredients. Only when this is done, can a reputation for uniformly high quality of product be gained.

If a feed manufacturer does not make chemical analyses at frequent intervals of the ingredients he uses and of his mixed feeds, he must fully consider the variations in the composition of the ingredients. Otherwise, the formula feeds may fall below their guarantees. To be safe, the guarantees for protein and fat must be sufficiently below the average composition, and the fiber guarantee enough above the average, so that the feeds will always meet the guarantees.

961. Lower-grade feeds.—A large proportion of the formula feeds are made of only high-grade ingredients. Others, especially some of those for cattle, contain more or less of cheaper products, such as ground grain screenings, oat hulls, and oat mill by-product (oat mill feed). These materials have a definite

feeding value and can be used best when intelligently combined in reasonable proportions with feeds of higher value. In particular, molasses adds to the palatability and usefulness of a mixture containing considerable grain screenings.

Formula feeds of this kind are sometimes economical when honestly sold for what they actually are. In purchasing such feeds one should use good judgment and not pay more than the product is really worth, as shown by the guaranteed composition and ingredients. Particular attention should be paid to the fiber guarantee. For example, high-quality formula feeds for dairy cows should have no more than 10 to 12 per cent fiber. If the fiber guarantee for the feed is over 12 per cent, it probably contains considerable of a low-grade ingredient.

962. Open formulas and closed formulas.—Most of the formula feeds are made with what are called "closed formulas." In this method the minimum percentages of protein and fat and the maximum percentage of fiber are guaranteed. Also the ingredients in the feed are usually stated on the feed tags, for this information is required under the feeding stuff laws in most states. However, the amount of each ingredient is not specified. In the "open-formula" method, which has been used chiefly by co-operative organizations of farmers in manufacturing formula feeds, the number of pounds of each ingredient in a ton of the mixture is also stated.

The open-formula method has certain advantages, but also certain disadvantages. The exact amount of each ingredient is known at a glance, and a farmer can easily compare the cost of the feed with the cost of making the same or a similar mixture on his own farm. Also, the amounts of digestible protein and of total digestible nutrients in the mixture can readily be computed, and the computations can be checked by anyone from such tables as Appendix Table I of this volume. The amounts of digestible protein and of total digestible nutrients are usually stated on the feed tag, along with the open formula. These figures are necessary, if one desires to compute a balanced ration accurately in accordance with the feeding standards.

Such data are not commonly given by manufacturers of closed-formula feeds, and, if given, the accuracy of the figures cannot be checked, because the amounts of the various ingredients are not known by the purchaser.

Unfortunately, there is no method by which the exact amount of any feeding stuff in a formula feed can be determined with accuracy. The best that can be done by a skilled microscopist is to ascertain whether any particular ingredient is present and to estimate approximately the proportion in which is occurs. The laws can be enforced that require the ingredients in a formula feed to be declared, for the microscopist can testify definitely on the witness stand that he has or has not identified any particular ingredient in the feed.

On the other hand, a law requiring that the manufacturer guarantee the amount of each ingredient in a formula feed could not be enforced. This is because the amounts of the various individual ingredients could not be determined with sufficient accuracy to serve as a basis for prosecution when the law was violated.

One of the reasons why nearly all private manufacturers of formula feeds have been unwilling to use the open-formula plan is that this might make possible unfair competition from unscrupulous competitors. Such competitors could print the same formulas on the feed tags, but cheapen the actual composition of their feeds by making changes in the proportions of various ingredients. Nevertheless, they could meet the same guarantee of ingredients and of content of protein, fat, and fiber. Therefore, they could not be prosecuted under any feeding stuff law. Such an unscrupulous manufacturer could sell his cheaper feeds at a lower price than the first concern could sell the feeds which had been made according to the published formulas. Yet, he might claim that his feeds were the very same products as those made by the honest manufacturer.

In addition, if a feed manufacturer believes that through knowledge and experience he has developed formulas that are particularly efficient, he may naturally hesitate to give this information to his competitors by using the open-formula plan.

963. Mixing feed on the farm.—Statements are sometimes made that it is difficult to mix on the farm several ingredients into a mixture that is sufficiently uniform to produce the best results in stock feeding. As a matter of fact, it is relatively simple, except in the case of a mixture made up of many ingredients, such as some poultry mashes, pig starters, or mixtures for young dairy calves.

One should first decide on the amount of each ingredient to be put in each ton or each 1,000 lbs. of the mixture, and write down this formula, so it can be followed exactly. Then a smooth, tight floor should be swept well, and the ingredients assembled. Scales should be at hand to weigh the feed, if full 100-pound sacks of each ingredient are not used.

Some of the ground grain, if it is the chief ingredient, should be spread on the floor to a depth of a few inches. Then a layer of each of the other ingredients should be distributed over the grain, and the process repeated until a long pile has been made, two or three feet deep. If only a small amount of some ingredient is used, as in the case of salt, this should be distributed evenly over the top of the pile. If a very small quantity of some mineral or vitamin supplement is to be included, this should first be well mixed with several pounds of some fine feed ingredient, before being added to the pile.

Finally, starting at one end, the feed is shoveled into a new pile of the same shape, a convenient distance from the first pile. Shoveling the mixture over three times will usually make it sufficiently uniform. Where a large amount of feed is mixed on a farm each year, it is advantageous to use one of the small feed mixers that have been developed for farm use.

964. Premixes.—To aid the smaller formula feed manufacturer or the feed dealer in making complicated mixtures, premixes are manufactured, for mixture with the ordinary feed constituents. These contain the important but very small amounts of certain vitamin supplements or trace mineral supplements needed, for example, in poultry mashes. In a premix, the vitamin and trace mineral supplements have been very thoroughly mixed with a certain amount of a carrier, which is usually one of the ordinary feed ingredients.

These are designed to supply the proper amounts of vitamins or trace minerals, or both, when the correct percentage of the premix for the particular kind of animal is included in a formula feed. If available, such a premix can be used by a farmer in making up concentrate mixtures on the farm.

965. Storage of concentrates.—If feeds contain too much moisture, they will heat and mold when stored, especially in warm weather. The rate and degree of spoilage depend on the air temperature and humidity, as well as on the percentage of water in the feed.

Heating or molding not only decreases the palatability and general nutritive value of a feed, but still more important, it seriously reduces the vitamin content, especially of carotene. As has been stated previously, the loss of carotene in a feed mixture is more rapid when the mixture contains meat scrap, tankage, dairy by-products, or certain mineral supplements. (195)

For storage without injury, ground grain must be drier than the whole grain. When molasses is included in a feed mixture, the water content may be brought up to an unsafe level, if it is already near the danger point. This is because molasses contains much more water than most other concentrates.

To be stored safely in warm weather for any long period, the percentages of water in various feeds should not exceed the following:[177] Ground corn, 13.0; whole shelled corn, 14.7; ground oats, 12.3; ground wheat, 12.0; ground sorghum grain, 13.0; wheat bran, 13.0; wheat shorts, 12.7; corn gluten meal,

11.2; cottonseed meal, expeller, 12.0; cottonseed meal, prepress solvent, 13.0; fish meal, 10.0–12.0; meat-and-bone scrap, 10.6; linseed meal, 11.0; soybean oil meal, 44 per cent protein, 13.1–14.5; soybean oil meal, 50 per cent protein, 15.5; alfalfa leaf meal, dehydrated, 15.5.

966. Antibiotic feed supplements. —The discovery in 1949 that certain antibiotics can increase the rate of growth of chicks and young pigs opened up a new development in swine and poultry feeding. Since then literally hundreds of experiments have been conducted with various antibiotics under different conditions.

The antibiotic feed supplements on the market generally supply not only an antibiotic or a mixture of antibiotics, but also vitamin B_{12}. These supplements are produced through the growth of microorganisms that synthesize the antibiotic and also B-complex vitamins.

At first such feed supplements were often called APF, or animal protein factor, supplements. Now a supplement used for its antibiotic activity is called an *antibiotic feed supplement.* A supplement supplying both an antibiotic and vitamin B_{12} is called an *antibiotic-vitamin B_{12} supplement.*

A suitable antibiotic feed supplement will generally, but not always, increase appreciably the rate of gain of pigs, of chicks, broilers, and poults, and of dairy calves during the first 2 or 3 months of age. In most such cases the antibiotic will very slightly reduce the amount of feed required per pound of gain.

The antibiotics most commonly used thus far as feed supplements are aureomycin (chlortetracycline), terramycin (oxytetracycline), penicillin (a stabilized form), and bacitracin. Certain other antibiotics are much less effective growth stimulants or have no such effect.

Several extensive reviews have been published, which summarize the results of the many experiments with antibiotic feed supplements for the various classes of farm animals.[178] Only a very brief summary can be given here of the data. Further information on antibiotic feed supplements is given in the chapters dealing with the feeding of each kind of stock.

The causes of the growth-stimulating effect of certain antibiotics are not entirely known. It is believed that an important effect is a reduction in the number of detrimental bacteria in the digestive tract, especially under insanitary conditions of housing and management.

Supporting this view are English experiments in which chicks placed in isolation boxes immediately after being hatched showed no response to a penicillin supplement.[179] On the other hand, when a small amount of intestinal contents of normally housed chicks was mixed with the feed, penicillin gave a marked growth stimulation. Similarly, in an experiment at Notre Dame University chicks raised under germ-free conditions did not respond to an antibiotic supplement.

It was found in these studies that the intestinal wall was thinner in the uninfected chicks or in the infected chicks fed the antibiotic than in chicks raised under normal conditions. This might increase the efficiency with which nutrients are absorbed.

In certain recent experiments chicks kept under practical conditions have responded much less, or not at all, to an antibiotic feed supplement, while in previous years the growth stimulation on similar rations had been marked.[180] It is believed that this difference was due to the reduction in harmful bacteria brought about by the continued use of an antibiotic supplement in the preceding years.

An antibiotic feed supplement tends to increase appetite and feed consumption. It may also stimulate the pituitary gland, so that more growth hormone is produced. Possibly, an antibiotic supplement may increase the efficiency with which protein is utilized, or decrease the need for certain vitamins. Also, certain studies indicate that an antibiotic feed supplement may increase the assimilation of calcium. Experiments have shown that an antibiotic supplement does not generally increase the digestibility of a ration.

A beneficial effect of an antibiotic-B_{12} feed supplement may be due to the B_{12} content as well as the effect of the antibiotic.

In most of the experiments with dairy calves, especially those weaned from milk at a very early age and fed a milk substitute, a suitable antibiotic feed supplement has generally increased the gain during the first 2 or 3 months. However, by the time the calves are 6 months old or older, there may be little or no difference in weight. In some trials the antibiotic has reduced trouble from scours during the first few weeks.

It has generally not been beneficial to add an antibiotic or antibiotic-vitamin B_{12} feed supplement to ordinary rations for dairy cows, for dairy heifers over 4 to 6 months of age, or for brood sows. Conflicting results have been secured from antibiotic feed supplements with beef cattle and sheep.

As is shown in Chapter XXXVI, the results have also differed in experiments where an antibiotic feed supplement has been added to rations for laying hens. The supplement often does not increase the egg production of hens fed a nutritionally complete ration which are laying at a high level, but may be beneficial at a lower level of production or with a poorer ration.

An antibiotic-vitamin B_{12} feed supplement is now included in a large proportion of the commercial mixed feeds, or "formula" feeds, for chicks and broilers, for growing and fattening pigs, and for young dairy calves (especially in milk replacers). The amount of such a supplement to be added to a feed mixture is so small (usually only 10 lbs. or less per ton) that it is difficult to mix it thoroughly by hand.

Many different antibiotics have been discovered, and several different antibiotic feed supplements are on the market. The effectiveness of various antibiotics apparently differs widely, and some produce no increase in growth. The reputation of the feed manufacturer for producing feeds of high quality and efficiency is therefore the best guide in purchasing formula feeds containing an antibiotic feed supplement.

967. Arsonic supplements; surfactants.—In a few experiments certain *arsonic compounds* (including arsanilic acid and other derivatives of arsonic acid), when added to a good ration, have generally, but not always, had an effect upon chicks and poults somewhat similar to that of an antibiotic. In certain trials an arsonic supplement has even stimulated growth when added to a ration containing an effective antibiotic. There is as yet but little experimental data concerning the effect of an arsonic supplement on laying hens.

Data are yet too limited to show definitely whether there will be an appreciable advantage for healthy young pigs from adding an arsonic supplement to a good ration that contains an effective antibiotic. In herds where there has been much trouble from dysentery in young pigs, an arsonic supplement may reduce the trouble.

The data concerning the effect of an arsonic supplement on young dairy calves are yet too limited to warrant conclusions. In Illinois experiments with fattening lambs it was concluded that 3 arsonic supplements tested were not beneficial.[181]

If an arsonic supplement is used, care must be taken so that safe levels are not exceeded. Experiments have shown, when properly fed, meat does not contain as much arsenic as permitted under regulations. As a precaution, the law requires that feeds containing such compounds must not be fed for at least 5 days before slaughter for human food.

Further information on arsonic supplements for pigs, poultry, and dairy calves is given in the chapters dealing with these classes of stock.

Much interest has been shown in the addition of certain surfactants (surface active agents) to feeds. In most of the experiments so far conducted, mostly with chicks and young pigs, little effect has been noted.

Tests with a new "chemobiotic" (tetra alkylammonium stearate) have given variable responses when added to rations

of ruminants and pigs. No apparent benefit was obtained in tests at Purdue or Iowa while Montana and Washington have reported increases in gain and feed efficiency from its use in beef cattle rations. Further information about surfactants is given in the chapters dealing with the feeding of swine, poultry, and dairy calves.

968. Complex mineral or vitamin mixtures; enzyme preparations; stock tonics.—Many complex mineral mixtures for stock feeding are extensively advertised, as are also preparations including both minerals and vitamins. Some of the mineral mixtures are honest efforts to supply at a reasonable price the minerals which may be lacking in certain rations. Extravagant claims are made for others, or they are sold at excessively high prices or are even of poor quality.

Many commercial mineral mixtures are high in calcium and rather low in phosphorus. This is because ground limestone or another calcium supplement is so much cheaper than a safe phosphorus supplement. Such a mineral mixture is generally very uneconomical and may even be detrimental where the animals already have plenty of calcium but lack phosphorus.

It has been pointed out in Chapter VI that simple mineral mixtures, such as are there recommended, will produce just as good results as complex mixtures that contain a large number of ingredients. (**187**) One cannot therefore afford to pay much more for a commercial mineral mixture than it would cost to make up a suitable mixture on the farm.

The vitamin requirements of farm animals have been considered in detail in Chapter VII. It has there been shown that, for all livestock except poultry, an ample supply of the necessary vitamins can generally be provided in rations made up of common feeds, without the use of special vitamin supplements. There is usually no benefit from adding yeast to ordinary rations, except in the case of poultry or swine fed rations deficient in B-complex vitamins. (**210**)

In spite of claims that are sometimes made to the contrary, there is no scientific evidence that any mineral mixture or vitamin supplement will prevent or cure Bang's disease (contagious abortion) in cattle. This disease must be clearly distinguished from the rare cases of abortion that may be produced by a serious lack of vitamins or minerals.

Sometimes claims are made that certain enzyme preparations will greatly improve livestock rations. The author knows of no scientific evidence that such preparations improve ordinary rations. It has been shown in Chapter IV that methods which have been exploited for fermenting, malting, or pre-digesting feeds do not cause any saving of feed or result in greater production. (**94**)

In spite of the advice of the experiment stations to the contrary, some farmers still spend money for various products called "stock tonics," etc. Tests of many stock tonics by the experiment stations show clearly that there is generally no advantage in their use. Farm animals managed with reasonable care have appetites which do not need stimulating. Sick animals or those out of condition should receive specific treatment rather than be given some cure-all.

The testimonials which the stock-tonic companies advertise are readily explained. The stock tonics are usually accompanied by directions which advocate liberal feeding and good care for the animals to be fed, in order to "secure the benefits from the tonic." The farmer therefore feeds and cares for his stock better than ever before and secures better results, due not to the tonic but to following the directions which accompanied it. Rather than purchase advice with costly tonics, the wise feeder will secure it in standard agricultural papers and books, or from the experiment stations and the United States Department of Agriculture.

VI. Miscellaneous Concentrates and Other Products

969. Apples and other fruits.—Windfall and surplus apples and other fruit can sometimes be fed advantageously to stock. Apples, peaches, plums, and even pears contain somewhat more dry matter than do

such roots as mangels and rutabagas. The chief nutrients are sugars, and fruits are extremely low in protein.

In a Virginia experiment in which dairy cows were fed 36 lbs. of apples per head daily in addition to hay and concentrates, it was concluded that a pound of dry matter in the apples was nearly equal to a pound of dry matter in corn silage and slightly superior to a pound in hay.[182] On this basis apples would be worth about 60 per cent as much per ton as corn silage. If cows have access to all the apples they can eat, as in an orchard where there are many on the ground, serious digestive disturbance may result.

In Washington tests good results were obtained when fattening lambs were fed 0.9 to 1.5 lbs. of apples per head daily in addition to hay and grain.[183] Thus fed, apples were even equal to corn silage in value per ton. When larger amounts of apples were fed the results were less satisfactory.

Good silage can be made by chopping a mixture of about 80 per cent by weight of apples and 20 per cent of alfalfa or other good hay, or else 60 per cent of apples and 40 per cent of wilted green hay crop. The loss by drainage is excessive if apples are ensiled alone. Apple-alfalfa silage was about equal to sunflower silage for dairy cows in Washington tests.[184] Silage can be made similarly from apple and pear cores and peelings.[185]

In California tests cows readily ate 20 to 30 lbs. of peaches a day. Only a few of the pits were swallowed.[186] Pears were not quite so palatable. When cows were fed more than about 15 lbs. of fresh prunes a day, scouring resulted. Smaller amounts were satisfactory. Cows could be allowed all the fresh grapes they would eat. None of these fruits injured milk flavor. Dried fruits of these kinds were also satisfactory in suitable amounts.

When apples replaced part of the grain for pigs in Utah trials, it required 9 to 15 lbs. of apples to equal 1 lb. of grain.[187]

In Florida trials fattening cattle made good gains when fed fresh grapefruit with hay, cottonseed meal, and 2 lbs. of corn a day.[188] Well-grown cattle can eat whole grapefruit, but for young animals it is best to quarter or slice the fruit. In another Florida test oranges were less satisfactory for fattening cattle, unless they had been grated to remove the outside of the peel.[189] Pigs made good gains on tangerines when fed an efficient protein supplement, and still better gains when also fed some corn.[190]

A ration of ripe olives and alfalfa produced satisfactory gains on lambs in an Arizona test.[191]

Chopped pineapple tops, or crowns, which form about 7 per cent of the weight of the fresh fruit, were palatable and about equal to green Napier grass as the only roughage for dairy cows or dairy heifers in Hawaiian experiments.[192] The cows ate 60 lbs. or more of the tops per head daily.

In a Guatemala trial ripe bananas, including the skins, were a satisfactory and economical feed for growing and fattening pigs, when as much as 2 lbs. of bananas was fed with each pound of a high-protein concentrate mixture.[193]

In Hawaiian trials bananas and avocados were economical supplemental feeds for laying hens, but the feeding of papaya over a long period of time produced detrimental results.[194]

970. Apple pomace; apple pectin pulp.—*Wet apple pomace* is the by-product when the juice is expressed from apples for cider or vinegar. It may be fed fresh, it may be ensiled, and it is sometimes dried to make *dried apple pomace.*

Wet apple pomace and apple pomace silage have about 21 per cent dry matter, in comparison with 27 per cent for silage from well-matured corn, and they are very low in protein. Though apple pomace silage is slightly lower in total digestible nutrients than average corn silage, it has proven about equal to corn silage in value per ton for dairy cows.[195] It should be fed after milking, to avoid tainting the milk. Unless stray box nails are removed from the apples or pomace at the mill, there may occasionally be injury to cattle from this source.

Dried apple pomace has given satisfactory results when used like dried beet pulp in dairy rations, and has been worth 75 per cent as much per ton as dried beet pulp or even more.[196] Fed as one-third the concentrates to fattening cattle in a Washington trial, dried apple pomace produced slightly less rapid gains than did dried molasses-beet pulp.[197] Because more protein supplement was needed with it, the apple pomace was worth only 57 per cent as much as the dried molasses-beet pulp.

Apple-pectin pulp is the residue left when the pectin is extracted from apple pomace for jelly making. *Dried apple-pectin pulp* was not as palatable to dairy cows as dried beet pulp in a test by the United States Department of Agriculture, when both were fed after soaking with water.[198] This difficulty can be avoided by mixing

the apple-pectin pulp with well-liked concentrates.

971. Bakery waste.—Sometimes stale bread or other bakery waste can be secured at a price that makes it an economical stock feed. Such waste can be used in place of part of the grain usually fed. Since bread usually contains over 30 per cent water, its feeding value is only about three-fourths that of corn or other grain.

Kiln-dried bakery waste is similar to grain in composition, except that it is lower in fiber and may be higher in fat. In Pennsylvania trials kiln-dried stale bread, fed after being moistened with water, was about equal to corn for pigs on pasture, but was constipating unless fed with some laxative feed.[199] Stale crackers were somewhat less valuable.

972. Cassava meal.—This by-product, also called tapioca meal, manihot meal or manioc meal, is produced in the manufacture of starch from the roots of the tropical cassava. It is rich in nitrogen-free extract and low in fiber, but is unusually low in protein and fat. It may be used as a substitute for part of the grain in feeding dairy cows and other stock, being approximately equal to grain in value, except for its lowness in protein.[200] In German trials it was concluded that not more than 10 per cent should be included in a ration for chicks, or the feed consumption would be decreased.[201]

973. Chicken litter.—Because ruminants can use non-protein nitrogen as a partial substitute for protein, experiments have recently been conducted at the Arkansas Station to find whether chicken litter, including the manure, could be used as a substitute for ordinary protein supplements in feeding beef cattle and sheep.[202] The dry chicken litter had an average of 4.6 per cent nitrogen, equivalent to 28.8 per cent crude protein. About one-fifth of the nitrogen was uric acid, which is the chief nitrogenous waste product in the case of birds.

In a test with ewes during gestation and lactation, the results were satisfactory when 23 per cent of dry chicken litter was included in the concentrate mixture, replacing soybean oil meal. In a trial with fattening lambs, 23 or 42 per cent of dry chicken litter was included in a pelleted mixture having 10 per cent of cane molasses. The gains were nearly as good as on a ration with cottonseed meal as the protein supplement. On the basis of feed required per 100 lbs. gain, 100 lbs. of chicken litter was equal to 63 lbs. other concentrates minus 15 lbs. hay.

Differing from these results, in a trial with fattening steers, the gain was decidedly less on a mixture containing 25 per cent dried chicken litter than on the check concentrate mixture, unless considerably more feed was given the steers fed chicken litter. On the basis of the feed required per 100 lbs. gain, 100 lbs. of chicken litter replaced only 9.2 lbs. other concentrates minus 28.8 lbs. hay.

974. Citrus pulp and other citrus by-products.—*Citrus pulp* is a by-product of citrus-canning factories, which make citrus fruit juices, canned fruit, and other products. It consists of the peel, the residue of the inside portion, usually including the seeds, and occasional cull fruits, with or without the extraction of part of the oil of the peel for flavoring extracts. Certain factories remove the seeds, which are processed for oil production, with *citrus seed meal* as a by-product. Citrus pulp is generally dried and ground, and sold as *dried citrus pulp*. The finer particles may be separated and marketed as *citrus meal*, usually at a slightly lower price.

Dried citrus pulp and molasses is also made, usually containing 10 to 33 per cent of citrus or cane molasses.

Before drying the pulp, lime is added to free water which is chemically bound to constituents of the pulp. Then the pulp is pressed to remove as much of the juice as possible. This may be condensed by evaporation to form *citrus molasses*.

Dried citrus pulp somewhat resembles dried beet pulp in composition and nature. It is a little higher in total digestible nutrients, having 74.9 per cent, but is very low in digestible protein, with only 2.7 per cent. Because of the lime added in the drying process, it has 2.04 per cent calcium, but the phosphorus content is only 0.15 per cent.

Dried citrus pulp is made chiefly from grapefruit or orange residue, but in some districts may contain lemon residue. There is not much difference in the composition or value of pulp from the various kinds of citrus fruits, except that lemon pulp is less palatable.

Dried citrus pulp is fed chiefly to dairy cattle and is a satisfactory substitute for dried beet pulp. In 3 Florida experiments it was about equal to dried beet pulp for dairy cows when forming as much as 40 per cent of the concentrate mixture.[203] In other tests it was not considered quite equal to dried beet pulp for milk production.[204] In 5 Texas

trials with dairy cows, dried citrus pulp was nearly equal to corn-and-cob meal (not including husks), when forming half of the concentrate mixture.[205] In an Arizona test dried grapefruit pulp increased the milk production of dairy cows that had declined in milk yield when fed only alfalfa hay.[206]

Though citrus pulp is less palatable than dried beet pulp, there is generally no difficulty in getting cows to eat a concentrate mixture containing it. If a mixture with a large percentage of citrus pulp is to be fed, it is well to increase the proportion gradually. In most of the tests the flavor of the milk has not been affected by dried citrus pulp.[207]

In Arizona trials dried grapefruit pulp was a satisfactory substitute for other concentrates for dairy heifers fed alfalfa hay or on pasture.[208]

Dried citrus pulp is a good substitute for part of the grain in rations for fattening cattle. In Arizona trials it was equal to rolled barley when replacing half of the grain.[209]

Used as a partial substitute for grain in fattening cattle, dried citrus pulp was equal to ground snapped corn, including the husks, in Florida and Texas trials.[210] In the Texas tests the ration tended to be too laxative when it formed one-half of the concentrate mixture. For steers on excellent pasture, dried citrus pulp was satisfactory as the only concentrate in Florida trials, being worth more than cane molasses.[211]

Dried citrus pulp is not suited for use as any important part of a ration for swine[212] or poultry.[213] In a Florida trial 5 per cent of dried citrus meal, (the finer particles) could be satisfactorily fed to pigs.[214]

Dairy or beef cattle eat fresh citrus pulp readily after they become used to it. The pulp may also be ensiled, preferably with chopped hay or fodder, as it is very high in water. When ensiled in trench silos, the shrinkage in weight of pulp was 21 to 43 per cent in Florida and Arizona tests.[215] In the Arizona trials fattening cattle would not eat as much grapefruit-pulp silage as of hegari sorghum silage. Considering the shrinkage of the grapefruit-pulp silage, it was not considered economical, unless the cost of the pulp at the silo was less than 30 per cent of the cost of hegari silage.

Citrus molasses, made from the juice pressed from citrus waste at canning factories, contains nearly as much sugar as does cane molasses. Although it has a very bitter after taste to humans, it is consumed readily by cattle and may be fed them much like cane molasses. As much as 6 lbs. a day has been fed satisfactorily to fattening cattle to replace part of the grain, and it has even been fairly satisfactory as the only concentrate for fattening cattle on excellent pasture.[216] When replacing not more than half the grain for fattening cattle citrus molasses has been nearly equal to ground snapped corn, including the husks, and worth slightly less than ground milo.

In Florida trials pigs did not at first like concentrate mixtures containing citrus molasses, but after a week ate mixtures containing as much as 30 to 40 per cent of the molasses.[217] Fed as 10 per cent of the ration, the molasses was worth 91 per cent as much as corn. The value decreased if the proportion of molasses became larger. Citrus molasses is not liked by horses and mules.

Ten per cent of citrus molasses in a ration for chicks was satisfactory in one Florida trial, but not in another.[218]

Citrus seed meal, the by-product in processing hulled citrus seed for oil is rich in protein, having over 30 per cent. Florida tests show that it is a satisfactory protein supplement for cattle, but that it is poisonous to poultry and does not give good results when used in swine rations.[219] When used as the protein supplement for fattening cattle, citrus seed meal containing 35 per cent protein was fully equal to cottonseed meal of low grade, having 36 per cent protein.

975. Garbage; processed garbage.—In the vicinity of some cities, garbage is used extensively for swine feeding. Generally the garbage is fed by contractors who purchase the collected garbage from the cities or else collect it themselves under rigid rules. To prevent the spread of disease, the cooking or sterilization of garbage is now required by law in practically all our states.

Garbage varies greatly in composition and feeding value, but on an average and allowing for normal losses of hogs by death, a ton of city garbage may be expected to produce 35 to 40 lbs. of marketable live weight of hog, deducting the pork made from any feed supplied in addition to the garbage.[220] Garbage of excellent quality, such as that from large hotels and restaurants, may be worth twice as much, or even more. In prosperous times city garbage has a considerably higher feeding value than during a depression. The garbage on farms can be well utilized by feeding it to swine or poultry.

Very often, swine are not fed grain or other feeds in addition to garbage at gar-

bage-feeding plants, because garbage is so much cheaper. To prevent rickets, it may be necessary to feed some field-cured alfalfa hay or a vitamin D supplement.

Hogs fattened exclusively on garbage shrink rather more than grain-fed hogs on shipment to market, have a slightly lower dressing percentage, and may yield pork that is somewhat soft. It is also of interest that the lean meat of garbage-fed hogs is lower in thiamine content than that from grain-fed hogs.

Sometimes city garbage is processed and dried to produce *processed garbage* and to recover some of the fat for industrial uses. This product, also called "garbage tankage" or "table scrap meal," is much different from digester tankage or meat scrap, as it has only 17 to 23 per cent protein.

Processed garbage is not a satisfactory substitute for fresh garbage, apparently because of unpalatability.[221] It can be used to replace part of the tankage or fish meal in swine rations, but does not give good results when used as the only protein supplement for young pigs, even when they are on good pasture.[222] Processed garbage was not satisfactory as the only protein supplement for fattening lambs in Indiana tests, but the results were fair when equal parts of digester tankage and garbage tankage were used.[223] In Hawaiian tests dairy cows ate a mixture containing 25 per cent processed garbage satisfactorily, and chicks grew well when 20 to 30 per cent of processed garbage was included in a ration that also contained better protein supplements.[224]

976. Incubator waste eggs.—Incubator waste, consisting of infertile eggs and eggs that fail to produce live chicks, can be used for feeding swine and poultry. In Delaware and New York tests pigs gained satisfactorily on waste incubator eggs and corn.[225] On the average, 100 lbs. of the eggs replaced 17 lbs. corn and 21 lbs. of a trio-type protein supplement.

A considerable amount of raw egg white in the ration produces a nutritional deficiency disease in some animals, including pigs. This is because a compound in the raw egg white makes biotin (one of the B-complex vitamins) unavailable.[226] This compound is destroyed by cooking. However, in the Delaware and New York tests, there was no such trouble when pigs were fed raw incubator waste eggs.

Experiments have shown that incubator waste that has either been boiled and run through a food chopper or been dried, is a good addition to a ration for chicks.[227] The incubator waste should be heated high enough to kill any disease germs.

977. Kelp; other seaweed.—Dried kelp and also proprietary mixtures consisting chiefly of dried kelp, or kelp meal, are sold as supplements for livestock. Dried kelp, or kelp meal, is prepared from giant seaweeds, called kelp. It contains over 30 per cent of mineral matter, including 0.15 to 0.20 per cent of iodine and also various other minerals.

Several experiments have been conducted by various experiment stations to find whether or not there is a benefit from adding kelp to the usual type of well-balanced rations for various classes of livestock.[228] Similar experiments have been conducted with Manamar, a proprietary mixture consisting chiefly of dried kelp and fish meal.[229]

After considering the results of these various tests, it is the opinion of the author that it has not been proved in scientific investigations by the experiment stations that rations containing kelp will generally produce results that are superior to those that can be obtained on rations that contain no kelp, which have no lack of iodine or the other essential minerals, and which provide sufficient protein and protein of proper quality.

In the coastal areas of some countries other kinds of seaweed are sometimes used as a partial substitute for other roughage, especially for cattle or sheep. Also, some dried *seaweed meal* is made from certain species of seaweed. In an English test, when used as 10 per cent of the concentrate mixture for dairy cows, seaweed meal was of low palatability and was rated as having a value equal only to a mixture of 7 parts of oat feed (oat-mill by-product) and 1 part of common salt.[230] In a Canadian experiment the addition of 2 to 6 per cent of dried seaweed meal to a ration for bacon pigs did not increase the gain or improve the carcass quality.[231] In another Canadian trial dried seaweed meals from two species of seaweed were poorly digested by hens.[232]

978. Olive pulp.—Olive pulp, the by-product in expressing oil from olives, has a very low feeding value if it contains the pits, for they form about 40 per cent of such pulp. In an Italian test olive pulp was worth only one-third as much as corn when it formed 30 per cent of the concentrate mixture for dairy cows.[233] In California trials including 20 to 23 per cent of ground dried olive pulp, including the pits, in a ration for pigs reduced the gains and it took 4 lbs. of the olive pulp to equal 1 lb. of other feed.[234] No

better results were secured with olive pulp without pits.

979. Pear by-products.—*Dried pear pomace,* containing 13 per cent fiber, was equal to dried beet pulp for dairy cows in an Oregon trial when forming one-quarter of the concentrate mixture.[235] In a California trial with fattening steers *dried pear pulp* containing 31 per cent fiber, was worth only 70 to 75 per cent as much as dried molasses-beet pulp, when fed as one-quarter of the concentrate mixture.[236]

In this experiment *pear molasses,* fed at the same level, was fully equal to cane molasses.

In a Washington trial silage made from a mixture of 3 to 4 parts of pear waste and 1 part pasture clippings was a fair substitute for grass silage in feeding dairy cows, but it furnished considerably less digestible nutrients.[237]

980. Pineapple bran, or pulp.—Pineapple bran, or pulp, is a by-product from the canning of pineapples. It consists principally of the outer shells and usually the cores. Pineapple bran is occasionally fed wet, but is usually dried, molasses sometimes being added.

Pineapple bran resembles dried beet pulp in composition, except that it contains very little protein and this is poorly digested. Also, the content of total digestible nutrients is slightly lower than in dried beet pulp.

Pineapple bran is a popular dairy feed in Hawaii and considerable amounts are shipped to the Pacific Coast states. In Hawaiian experiments good results were secured when it formed one-third to two-thirds of the concentrate mixture for dairy cows.[238] It was also satisfactory for work mules when forming half of the concentrates, and for pigs when used as 30 to 50 per cent of the concentrates. Sometimes pineapple bran is soaked before feeding and used as a substitute for silage in dairy rations. The wet or dry pineapple bran has also given good results when fed to fattening cattle in Hawaii.

981. Potato meal; potato pulp.—Cull or surplus potatoes can be dehydrated, or dried, to make *potato meal.* This is a satisfactory substitute for grain in feeding cattle or sheep, and if the potatoes are heated sufficiently in the drying process to cook them thoroughly, a limited amount of potato meal can be used in swine or poultry rations. It must be remembered that potatoes are low in protein and deficient in carotene and calcium. These lacks must be made good by other feeds.

Potato meal has been equal to grain when forming 20 to 25 per cent of the concentrate mixture for dairy cows.[239] In an English test it was satisfactory when it was fed as 61 per cent of the mixture, with oil cake making up the remainder.[240] It was also equal to grain as a substitute for part of it in Arizona, Colorado, and Nebraska trials with fattening cattle or lambs, but in an Idaho test air-dried potatoes did not give good results with fattening lambs.[241]

Dehydrated Potatoes

Dehydrated potatoes, or potato meal, can be substituted for part of the grain in feeding livestock. (From Connell, Colorado Station.)

The results with potato meal for swine and poultry have differed greatly, probably depending on how much the potatoes were heated in the drying process.[242] In some tests the results were good when potato meal formed 10 per cent of the ration for young pigs, 30 per cent for older pigs, and 10 to 20 per cent for poultry. In other trials potato meal has been unsatisfactory for pigs or chickens.

Dried potato pulp, or potato pomace, is the by-product in starch production from potatoes. It is slightly higher than potato meal in total digestible nutrients, but is low in protein. If lime is added in the drying process, the calcium content will be high.

In Maine trials dried potato pulp was palatable to dairy cows and was nearly equal to hominy feed when forming 20 per cent of the concentrate mixture.[243] It was unsatisfactory for chicks or growing chickens in Maine tests, even when only 5 to 10 per cent was included in the ration.[244]

982. Raisins and other dried fruits; grape pomace.—*Cull raisins* may be fed to

stock as a partial substitute for grain. They were worth 82 per cent as much as barley in a California test when replacing one-third the barley in a ration for fattening lambs.[245] Pigs also produced satisfactory gains when cull raisins replaced up to one-half the grain in a ration, but the value of the raisins was less than for lambs. In another California trial raisins were fully equal to grain when forming as much as 16 per cent of the ration for growing turkeys.[246]

Cull dried apples, figs, pears or prunes can similarly be used for feeding.[247]

Raisin pulp, a by-product in the production of seeded raisins or in the manufacture of syrup from raisins, is of much lower value than cull raisins, for much of it consists of stems and seeds. For fattening lambs it was worth only 59 per cent as much as barley in California tests, when replacing part of the grain.[248]

Grape pomace, or winery pomace, the refuse in the production of grape juice or wine, consists chiefly of the grape seeds and skins. It is of such low value, even when ground, that it should not be used for feeding. In California digestion trials it supplied less digestible nutrients than straw, and in a New York test it had no value whatsoever for pigs, when replacing part of the grain in a ration.[249]

982a. Sewage sludge.—The dried residue from septic-tank disposal of sewage is used for fertilizer. It has nitrogen equivalent to about 30 per cent of protein, much of which is non-protein nitrogen. It is very high in mineral matter, having about 40 per cent. In recent Illinois studies with steers it was found that they would readily eat 1 lb. per head daily of dried sewage sludge when it was mixed with palatable feeds, but with full-fed fattening steers the palatability of the ration and the gains were reduced when sewage sludge replaced part of the soybean oil meal.[250]

The nitrogen of the sludge was less digestible and not utilized so well as that in soybean oil meal. Some manner in which this material can be successfully used for feeding ruminants may be found in further studies.

In Illinois tests with baby pigs fed a purified synthetic milk, 4 to 5 per cent of dried activated sewage sludge was an adequate source of vitamin B_{12}. A larger percentage of the sewage sludge decreased growth.[251] In a similar test with chicks 2 or 10 per cent of sewage sludge was a satisfactory vitamin B_{12} supplement.

983. Sweet potato meal.—In the southern states many experiments have been conducted to determine the value of sweet potato meal, or dried sweet potatoes, for stock feeding. This is because sweet potatoes yield more dry matter and a greater feeding value per acre there than does corn or any other cereal. However, the cost per acre of growing sweet potatoes is considerably higher than for corn, because of the large amount of labor required, and the cost of dehydrating them is rather high.

Sweet potato meal is usually made from cull or surplus sweet potatoes. The sweet potatoes are usually dried at dehydrating plants. Where the climate is suitable, they can be dried outdoors by spreading them, after being shredded or sliced in a machine, upon a suitable hard surface.

Sweet potato meal is even richer than corn in nitrogen-free extract (chiefly starch) and is low in fiber. It is therefore nearly equal to corn in content of total digestible nutrients.[252] It is very low in protein, calcium, and phosphorus. Care must be taken to correct these lacks when a large allowance is fed. Sweet potato meal is fully as rich as well-cured alfalfa hay in carotene, if made from a variety with good yellow color. If made largely from peelings or trimmings, the value of sweet potato meal is decidedly lower.

Sweet potato meal is a good substitute for grain in feeding dairy cattle, beef cattle, and sheep. It is not liked well by horses or mules and had best not form more than one-half of the concentrate mixture. It is least useful for swine or poultry.

Several experiments have been conducted to compare sweet potato meal with ground corn or other grain as a carbohydrate-rich feed for dairy cows.[253] In some tests it has been equal to ground corn, when replacing a considerable part of the grain in a concentrate mixture. In other trials dried sweet potatoes have been worth 88 to 95 per cent as much as corn. Because of their high carotene content, dried sweet potatoes increase the vitamin A value and the yellow color of milk. In most of the experiments sweet potato meal has been equal or nearly equal to corn when forming up to 30 or 50 per cent of the concentrate mixture. The value has usually been somewhat less when it has replaced all the corn or other grain.

When replacing not over half the grain for fattening cattle sweet potato meal has generally been worth 95 to 100 per cent as much as corn, but may have a lower value when it replaces all the grain, as it

is less palatable than grain and is somewhat laxative.[254] In Georgia trials dried sweet potatoes were an excellent concentrate for wintering pregnant ewes, as the ewes thus fed tended to produce more milk after lambing.[255]

The results have differed greatly in experiments in which dried sweet potatoes have been fed to swine.[256] Fairly good results are usually secured when dried sweet potatoes replace not more than one-fourth the grain. When a larger proportion is fed, the gains of pigs have often been very poor. Similarly, the results have differed decidedly when dried sweet potatoes have been used in poultry rations.[257] It therefore seems best to use them for other classes of stock.

984. Tomato pomace.—Dried tomato pomace is a dried mixture of tomato skins, pulp, and crushed seeds resulting from the manufacture of tomato juice or catsup. It has 22.9 per cent protein and 15.0 per cent fat, but is high in fiber, having 30.2 per cent. Tomato pomace is high in thiamine, is fair in riboflavin, and has considerable carotene. It is used chiefly in special feeds, such as dog foods.

In Delaware tests dried tomato pomace was satisfactory for dairy cows when forming 15 per cent of the concentrate mixture, and wet tomato pomace was a good addition to a ration for pigs.[258]

QUESTIONS

1. What is the composition of cow's milk? To what extent is whole cow's milk used in stock feeding?
2. Compare the composition of skimmilk and whole milk.
3. Why should dairy by-products be pasteurized at the dairy plant before being brought back to the farm?
4. Compare the composition of buttermilk and skimmilk.
5. Discuss the use and value of skimmilk and buttermilk for swine. How should they be fed to have the greatest value?
6. What is the approximate value of 100 lbs. of skimmilk for swine in terms of tankage and corn?
7. Discuss the use of skimmilk and buttermilk for poultry.
8. Compare the composition of whey and skimmilk.
9. Discuss the use of whey for: (a) Dairy calves; (b) swine; (c) poultry.
10. Discuss the use of the following in stock feeding: (a) Dried skimmilk and dried buttermilk; (b) condensed buttermilk; (c) dried whey.
11. Describe the two methods used in processing meat by-products.
12. What is the approximate protein content of the most important grades of digester tankage and of meat scrap?
13. What is rendering-plant tankage, or reduction tankage?
14. Discuss the use and value of tankage and meat scrap for: (a) Swine; (b) poultry; (c) dairy cattle; (d) beef cattle; (e) sheep; (f) horses.
15. For what purpose is blood meal chiefly used in stock feeding?
16. What is the composition of fish meal? What are the chief types of fish meal?
17. Discuss the use and value of fish meal for: (a) Swine; (b) poultry; (c) other classes of stock.
18. Are any other meat or fish by-products used for stock feeding in your region?
19. Discuss the composition and nutritive value of: (a) Cane molasses; (b) beet molasses.
20. Discuss the use and value of cane and beet molasses for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) horses and mules; (e) swine; (f) poultry.
21. Discuss the use and value of any of the following that are important in your region: (a) Dried beet pulp and dried molasses-beet pulp; (b) wet beet pulp; (c) molasses feeds; (d) alfalfa-molasses feeds.
22. Compare the composition and value of corn distillers dried grains and rye distillers dried grains; of distillers dried grains with solubles and without solubles.
23. Discuss the use and value of distillers dried grains for: (a) Dairy cattle; (b) beef cattle; (c) sheep; (d) swine; (e) poultry.
24. What is the special value of distillers dried solubles?
25. For what purpose is dried yeast chiefly used in stock feeding?
26. How should a farmer decide whether to buy a commercial mixed feed or to prepare a suitable mixture on the farm?
27. What is meant by open formulas and closed formulas for commercial mixed feeds? What are the advantages of each?
28. Tell how you would prepare a concentrate mixture on the farm.
29. What are premixes?

30. Discuss the use of antibiotic feed supplements.
31. For what classes of stock are arsonic supplements used?
32. What is your opinion concerning the use of complex mineral or vitamin supplements?
33. Discuss the use of stock tonics.
34. Discuss the use and value of any of the feeds considered in Articles 969 to 984, which are assigned by your instructor.

REFERENCES

1. Blackwood, Morris, and Wright, Jour. Dairy Res., England, 7, 1936, pp. 228–237; Wilkie, Edwards, Fowler, and Wright, Jour. Dairy Res., England, 8, 1937, pp. 311–323; Wilson, Minett, and Carling, Jour. Hygiene, England, 37, pp. 243–253.
2. Eckles and Shultz, Minn., Jour. Dairy Sci., 14, 1931, pp. 189–197; see also: Beach and Clark, Conn. (Storrs) Rpt. 1904; Tretsven, Mont. Bul. 282.
3. Woodward, Shepherd, and Graves, U.S.D.A. Misc. Pub. 179.
4. Hughes and Feldmiller, Cal. Exten. Cir. 15; Goesmann, Mass. Rpts. 1884, 1885; Wilson, S.D. Bul. 136.
5. Horlacher, Ky. Rpts. 1921, 1922.
6. Bureau Anim. Indus., U.S.D.A., Rpt. 1946.
7. Robison, Ohio Bul. 316; see also: Ferrin and Johnson, Minn., mimeo. rpts.; Ellenberger and Aplin, Vt. Bul. 273; Henry, Wis. Rpt. 1895.
8. Headley, Nev. Buls. 125, 147.
9. Freeman, Mich. Cir. 53; Bohstedt, Fargo, and Beeson, Wis. Bul. 425.
10. Freeman, Mich. Quar. Bul., 16, 1933, No. 2; McCarty, Penn. Bul. 179; Fargo, Bohstedt, and Lacey, Wis. Bul. 454.
11. Fargo and King, Wis. Bul. 440.
12. Dvorachek, Ark. Cir. 38; Skinner and Cochel, Ind. Bul. 137; Robison, Ohio Buls. 316, 349; Morrison, Fargo, and Bohstedt, Wis., mimeo. rpts.; see also: Thompson and Voorhies, Cal. Bul. 342; Hughes, Cal., mimeo. rpt.; Osland and Morton, Colo. Bul. 381; Ferrin and McCarty, Minn., mimeo. rpts.; Joseph, Mont. Bul. 169; Headley, Nev. Buls. 114, 125; Headley and Wilber, Nev. Rpt. 1934; Loeffel, Nebr., mimeo. rpt.
13. Brown, Mich., Amer. Soc. Anim. Prod., Proc. 1930; Freeman, Mich. Cir. 53; Loeffel, Nebr., mimeo. rpt.; Morrison and Fargo, Wis., mimeo. rpts.
14. Ferrin and McCarty, Minn., mimeo. rpt.; Weaver, Mo. Bul. 247; McCarty, Penn. Bul. 179; Morrison and Fargo, Wis. Bul. 373; Fargo, Bohstedt, and Lacey, Wis. Bul. 454.
15. Johnson, Ark. Bul. 417; Culbertson and Evvard, Iowa, Amer. Soc. Anim. Prod., Proc. 1924; Headley, Nev. Buls. 164, 173, 175; Kuhlman and Wilson, S.D. Bul. 216.
16. Martin, Ky. Bul. 260; Walker, New Mex. Bul. 150; Bryant and Schlamb, N.D. Bul. 356; Cassel, Wash. Bul. 210.
17. Payne, Schumaker, and Bushnell, Kan., Poultry Sci., 24, 1945, pp. 93–94.
18. Morrison, Hulce, and Humphrey, Wis. Buls. 339, 362; Rupel, Wis. Bul. 404.
19. Morrison and Bohstedt, Wis. Buls. 319, 323.
20. Thompson and Voorhies, Cal. Bul. 342.
21. Braude, Jour. Min. Agr., Great Britain, 48, 1941–42, pp. 10–11.
22. Assoc. Amer. Feed Control Officials, Official Pub., 1956.
23. Id. Buls. 160, 179; Jacobson and Allen, Iowa Rpt. 1949–51, Part 1; Shaw and Beck, Kan. Rpt. 1938–40; Burch and Frye, La. Rpt. 1951; Ingham, Meade and Berry, Md. Bul. 319; Berry, Md. Bul. 330; Eckles and Gullickson, Minn. Bul. 215; Lindsey and Archibald, Mass. Bul. 253; Krauss and Crawford, Ohio Bimo. Bul. 137; Leighton and Huff, Tex. Prog. Rpt. 1482; Arrington and Reaves, Va., Jour. Dairy Sci., 31, 1948, pp. 1–9; Ellington and Knott, Wash. Bul. 178; Morrison and Rupel, Wis. Bul. 388; Rupel, Wis. Bul. 404; Bohstedt and Rupel, Wis., Amer. Soc. Anim. Prod., Proc. 1930; Willard, Wyo. Rpt. 1942; McCandlish, West of Scot. Agr. Col. Res. Bul. 7.
24. Cave and Atkeson, Kan. Rpt. 1936–38; N.H. Bul. 319.
25. Turk, N.Y., unpublished data.
26. Neidermeier, Zehner, and Allen, Wis. Bul. 492.
27. Fairbanks, King, Gobble, Krider, and Carroll, Ill., Jour. Anim. Sci., 3, 1944, pp. 250–256; Evvard, Culbertson, and Wallace, Iowa Bul. 278; Ferrin, Minn., mimeo. rpt.; Robison, Ohio Bimo. Bul. 192; Bohstedt, Fargo, and Ries, Wis. Bul. 428; Crampton, Sci. Agr., Canada, 11, 1931, pp. 347–350; see also: Whitehair and Hillier, Okla. Misc. Pub. MP-27.
28. Evvard, Culbertson, and Wallace, Iowa Bul. 278; Brown, Mich. Rpt. 1923; Ferrin and McCarty, Minn. Bul. 221 and mimeo. rpt.; Ferrin and Engebretson, Minn., mimeo. rpt.; Weaver, Mo. Bul. 247; Smith and Maynard, Utah Bul. 254; Bohstedt, Fargo, and Ries, Wis. Bul. 428.
29. For reviews of the experiments on dairy by-products for poultry, see Heuser, Feeding Poultry, 2nd Ed., 1955; Ewing, Poultry Nutrition, 4th Ed. 1951.
30. Krider, Becker, Curtin, and Van Poucke, Ill., Jour. Anim. Sci., 8, 1949, pp. 112–120; Briggs and Beeson, Ind., Jour. Anim. Sci., 11, 1952, pp. 103–111; Vohs, Maddock, Catron, and Culbertson, Iowa, Jour. Anim. Sci., 10, 1951, pp. 42–49; N.J. Rpt. 1931; Orr and Crichton, Scot. Jour. Agr., 6, 1923, pp. 63–67.
31. Ark. Rpt. 1942.
32. Id. Bul. 164; Eckles and Gullickson, Minn. Bul. 215; Ellington and Knott, Wash. Buls. 178, 208; Rupel, Wis. Bul. 404.
33. Thompson and Voorhies, Cal. Bul. 342; Evvard and Culbertson, Iowa, mimeo. rpt.; Vestal, Ind., mimeo. rpt.; McCampbell, Kan. Cir. 78; Aubel and Connell, Kan. Cir. 188; Ferrin and McCarty, Minn. Buls. 213, 221; Weaver, Mo. Bul. 247; Gramlich, Nebr. Bul. 176; Gramlich and Loeffel, Nebr., mimeo. rpt.; Helyar, N.J. Rpt. 1921; Grimes, Penn. Bul. 168.
34. Morrison, Fargo, and Thomas, Wis. Bul. 388.
35. Bohstedt and Fargo, Wis. Buls. 430, 438; Fargo and King, Wis. Bul. 440; Halpin and Holmes, Wis. Bul. 435.
36. Robison, Ohio Bimo. Bul. 224; see also: Terrill et al., Ill., Jour. Anim. Sci., 13, 1954, pp. 622–629; Guerin, Hoefer, and Beeson, Ind., Jour. Anim. Sci., 10, 1951, pp. 607–616; Texas Rpt. 1947–49; Cunha, Warwick, Ensminger, and Hart, Wash., Jour. Anim. Sci., 7, 1948, pp. 117–126.
37. Grimes, Sewell, and Cottier, Ala. Rpt. 1931–

32; Lampman, Petersen, and Wiese, Id. Bul. 270; Vestal, Ind. Rpt. 1930; Nebr. Rpt. 1935; Ohio Bul. 579; Gobble, Miller, Ziegler, and Bentley, Penn. Bul. 516.

38. Culbertson and Hammond, Iowa, mimeo. rpt.; Johnson, Minn., mimeo. rpt.; Loeffel, Nebr., mimeo. rpt.; Robison, Ohio Special Cir. 32.

39. Robison, Ohio Bul. 552.

40. Vestal, Ind., mimeo. rpts.; Aubel and Connell, Kan. Cir. 223; Ferrin, Minn., mimeo. rpt.; Kyzer, Clyburn, Jones, and Godbey, S.C. Cir. 65; see also: Aubel and Connell, Kan. Cir. 189; Heidebrecht, Ross, and MacVicar, Okla., Misc. Pubs. MP-13, MP-15.

41. Wilgus, Norris, and Heuser, N.Y., Jour. Agr. Res., 51, 1935, pp. 383–399; Ky. Rpt. 1939.

42. Cannon, Iowa, information to the author; Atkeson, Cave, and Riddell, Kan. Rpt. 1934–36; Archibald, Mass. Bul. 321; Petersen, Minn., information to the author; Dice, N.D. Bul. 286; Olson, S.D. Rpt. 1936.

43. Stanley and Walker, Ariz. Bul. 170; Rusk and Snapp, Ill. Rpts. 1935, 1936; Skinner and King, Ind. Bul. 428; Culbertson, Hammond, Beard, and Thomas, Iowa, mimeo. rpts.; McCampbell and Aicher, Kan., Annual Cattlemen's Round-up, 1938, 1939; Thalman, Nebr. Bul. 345; Wilson and Wright, S.D. Bul. 329.

44. McCampbell and Aicher, Kan., Annual Cattlemen's Round-up, 1938, 1939.

45. Miller, Cal., mimeo. rpt.; Harper, Ind. Bul. 470; Iowa Sta., mimeo. rpt.; Cox, Kan. Rpt. 1934–36; Jordan and Peters, Minn., mimeo. rpt.; Fox, Nebr. Bul. 211; Alexander, Nebr., mimeo. rpt.; Christensen, N.D. Bul. 286; Morrison and Kleinheinz, Wis. unpublished data.

46. Titus, Byerly, Ellis, and Nestler, U.S.D.A., Jour. Agr. Res., 53, 1936, pp. 453–465; Bird and Groschke, Flour and Feed, Oct. 1942.

47. Burkett, N.C. Bul. 189; Robison, Ohio Bimo. Bul. 223; Quick, Va. Bul. 176.

48. Archibald, Mass. Bul. 334.

49. Krauss and Monroe, Ohio Bul. 548.

50. Wagner and Elvehjem, Wis. Buls. 456, 461; Olcott, U.S.D.A., Soc. Expt. Biol. and Med. Proc., 54, 1943, pp. 219–220; Slinger, Evans, Kellam, and Marcellus, Canada, Poultry Sci., 23, 1944, pp. 431–436; Slinger, Pepper, and Hill, Canada, Poultry Sci., 34, 1955, pp. 919–922.

51. Runnels, Shor, and Tomhave, Del. Bul. 233; Wilder, Ostby, and Gregory, Ill., Poultry Sci., 34, 1955, pp. 518–523; Draper, Iowa Res. Bul. 326; Kan. Rpt. 1926–28; Gerry and Smith, Me., Poultry Sci., 33, 1954, p. 1089; Jordan and Jordan, Minn., Jour. Anim. Sci., 14, 1955, pp. 1211–1212; Jordan, Croom, and Jordan, Minn. Mimeo. Rpt. S-48; Naber and Morgan, S.C., Poultry Sci., 34, 1955, p. 39; Lillie, Menge, Sizemore, and Denton, U.S.D.A., Poultry Sci., 34, 1955, pp. 33–34; Kincaid, Copenhaver, and McClaugherty, Va. Rpt. 1950–53.

52. Weaver, Mo. Buls. 340, 376; Willman and Morrison, N.Y. (Cornell) Bul. 836; Robison, Ohio Bimo. Bul. 209, Ohio Bul. 617; Keith, Miller, Thorp, and McCarty, Penn., Jour. Anim. Sci., 1, 1942, pp. 120–125; Ellis and Madsen, U.S.D.A., Amer. Soc. Anim. Prod., Proc. 1939; see also: Heidebrecht, Ross, and MacVicar, Okla. Misc. Pub. MP-13.

53. Booth and Hart, Wis. Bul. 456; see also: Frey and Kratzer, Colo. Farm Bul. 7, 1945, No. 6.

54. Stewart and Mussehl, Nebr., Poultry Sci., 20, 1941, p. 450; Tenn. Rpt. 1953.

55. Grau and Williams, Cal., Poultry Sci., 34, 1955, pp. 810–816; see also: Willman and Morrison, N.Y. (Cornell) Bul. 730; N.J. Rpt. 1935; Robison, Ohio Bimo. Bul. 217; Dodi, Italy, Riv. Zootec., 28, 1955, pp. 43–45.

56. Willman and Morrison, N.Y. (Cornell) Bul. 730; Robison, Ohio Bimo. Bul. 217 and information to the author.

57. Edwards, Ga. Cir. 84; Vestal, Ind., mimeo. rpts.; Evvard, Culbertson, et al., Iowa, mimeo. rpts., and Amer. Soc. Anim. Prod., Proc. 1924; Hostetler, N.C., information to the author; Robison, Ohio Bul. 349; Godbey and Durant, S.C. Bul. 234; Wilson and Kuhlman, S.D. Bul. 192; Morrison and Bohstedt, Wis., mimeo. rpt.; Ala. and Tenn. Stations, data from U.S. Dept. of Agr.; see also: Headley, Nev. Rpt. 1950.

58. Evvard, Culbertson, et al., Iowa, mimeo. rpt.; Culbertson and Hammond, Iowa, mimeo. rpt.; Aubel, Kan. Cir. 207; Robison, Ohio Spec. Cir. 32; Grimes, Penn. Bul. 168; Kyzer, Clyburn, Jones, and Godbey, S.C. Cir. 65.

59. Vestal and Barrick, Ind. Rpt. 1941; Culbertson and Evvard, Iowa, mimeo. rpts.; Willman and Morrison, N.Y. (Cornell) Bul. 730; Robison, Ohio Bimo. Bul. 217; Kyzer, Clyburn, Jones, and Godbey, S.C. Cir. 65.

60. Vestal, Shrewsbury, Jordan, and Milligan, Ind., Jour. Anim. Sci., 4, 1945, pp. 63–67; Hilton, Sci. Agr., Canada, 19, 1938, pp. 121–137; Wood, Orr, and Crowther, Jour. Min. Agr., Great Britain, 53, 1928, No. 5.

61. Heuser, Feeding Poultry, 2nd Ed., 1955; Ewing, Poultry Nutrition, 4th Ed., 1951; Robertson, Carver, and Cook, Wash. Bul. 388.

62. Bryant and Stevenson, Va. Bul. 321.

63. Scott, Fla. Rpt. 1922; Henke, Iwanaga, Webster, and Morita, Hawaii Rpt. 1948–50; Corbett and Hall, Maine, information to the author; Ingham, Md. Bul. 342; Bartlett, N.J. Rpt. 1929; Monroe, Krauss, and Hayden, Ohio Bimo. Buls. 176, 178, 185; Ohio Buls. 497, 532; Campbell, Vt. Bul. 333; Ellington and Knott, Wash. Bul. 229; Woodward et al., U.S.D.A. Bul. 1272; Archibald, Dominion Expt. Farms, Canada, Pamphlet 17; De Lisle, Fisheries Dept., British Columbia, Canada, Rpt. on Edible Fishmeal, 1930.

64. Miller, Cal. Rpt. 1930 and mimeo. rpts.; Hunt, Md. Buls. 379, 398; Carmichael, Md. Rpt. 1937; Paterson, West of Scot. Agr. Col. Bul. 97.

65. Stephenson, Camp, and Noland, Ark., Jour. Anim. Sci., 10, 1951, pp. 1062–1063; Krider et al., Ill., Jour. Anim. Sci., 5, 1945, pp. 556–563; Terrill, Becker, Adams, and Mead, Ill., Jour. Anim. Sci., 11, 1952, pp. 84–91; Geurin, Hoefer, and Beeson, Ind., Jour. Anim. Sci., 9, 1950, pp. 94–100; Culbertson, Catron, Shearer, and Thomas, Iowa Rpt. 1949; Robison, Ohio Res. Bul. 699.

66. Stephenson and Clower, Ark., Poultry Sci., 31, 1952, pp. 936–937; Fuller, Ga., Poultry Sci., 32, 1953, p. 900; Petersen, Wiese, and Pappenhagen, Id., Poultry Sci., 32, 1953, p. 921; Hauge and Needham, Ind. Rpt. 1952; Arscott and Combs, Md., Poultry Sci., 32, 1953, pp. 730–733; Johnson, Minn., Poultry Sci., 33, 1954, p. 1063; Halbrook, Buckler, and Smith, Mont., Poultry Sci., 32, 1953, pp. 1058–1068; Edwards, Dam, Norris, and Heuser, N.Y., Poultry Sci., 32, 1953, pp. 551–554; Hart, Higgins, and Wiley, R.I. Misc. Pub. 35; German, James,

and Sherwood, Tex. Prog. Rpt. 1106; Cravens, Halpin, and McGibbon, Wis. Buls. 466, 469.

67. Parkhurst, Gutowska, Fellers, et al., Mass., Poultry Sci., 23, 1944, pp. 58–64, 118–125.
68. Gobble, Penn. Bul. 553; Kyzer and Pace, S.C. Rpt. 1942.
69. Ind. Rpt. 1926; N.J. Rpt. 1928.
70. Bray, Francioni, and Gregory, La. Bul. 228; Singletary, Bray, and Davis, La. Bul. 368; Fletcher, Miss. Farm Res., 16, 1953, No. 2, Miss. Inform. Sheet 491.
71. Upp, La. Bul. 262; Polk and Barnett, Miss. Bul. 374; Heuser, Feeding Poultry, 2nd Ed.
72. Lush, La., Amer. Soc. Anim. Prod., Proc. 1935.
73. Marshall and Davis, Fla., Jour. Anim. Sci., 5, 1946, pp. 211–218; Marshall, Becker, and Davis, Fla., Jour. Dairy Sci., 29, 1946, pp. 801–808; Davis, Mehrhof, and Driggers, Fla. Rpt. 1946.
74. Rhian and Evans, Wash. Bul. 425.
75. Heuser, Feeding Poultry, 2nd Ed., 1955.
76. Halnan, Jour. Agr. Sci., England, 32, 1942, pp. 179–193; see also: Hostetler, N.C. Rpts. 1928, 1929; Tangauf and Detitius, Archiv. für Geflügelk, 8, 1934, p. 383.
77. Chem. and Eng. News, Sept. 22, 1952.
78. Kidder and Beardsley, Fla. Bul. 493; Chapman, Kidder, and Plank, Fla. Bul. 531.
79. Foreman and Herman, Mo. Res. Bul. 535.
80. Trimberger, Davis, Turk, and Loosli, N.Y. Farm Res., 21, 1955, No. 2; see also: Briggs and Heller, Okla., Jour. Agr. Res., 71, 1945, pp. 81–87.
81. For a review of feeding experiments with molasses, see: Scott, Use of Molasses in the Feeding of Farm Animals, Tech. Rpt. Series No. 9, 1953, Sugar Research Foundation.
82. Madsen, Colo. Farm and Home Res., 3, 1952, No. 9.
83. Beeson, Hickman, Bolin, Johnson and Rinehart, Id. Buls. 239, 251; Maynard and Greaves, Utah Bul. 250; Madsen and Nielsen, Utah Buls. 294, 306, 315.
84. Bohstedt, Roche, et al., Wis. Bul. 430; see also: Lindsey, Holland, and Smith, Mass. Bul. 118; Britnall, Miss. Cir. 38; Arnett, Mont. Rpt. 1929; Williams, Jour. Dairy Sci., 8, 1925, pp. 94–104; Grisdale, Canada Expt. Farms, Rpt. 1913.
85. Mather, Brockett, and Poulton, N.J., Jour. Anim. Sci., 12, 1953, p. 924.
86. Davis, Trimberger, Turk, and Loosli, N.Y. (Cornell) Bul. 914; Bohman, Trimberger, Loosli, and Turk, N.Y., Jour. Dairy Sci., 37, 1954, pp. 284–293.
87. Woodward et al., U.S.D.A. Bul. 1272.
88. Henke, Hawaii Bul. 73.
89. Evvard and Culbertson, Iowa, mimeo. rpts.; Gerlaugh, Ohio Bul. 463.
90. Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732; see also: Klosterman, Moxon, and Bentley, Ohio, A.S. Mimeo. Rpt. 94.
91. Melton, Willey, Jones, and Lyerly, Tex. Prog. Rpt. 1277; see also: Duitsman and Kessler, Kan. Cirs. 307, 322.
92. Grimes, Ala. Bul. 231; Templeton and Goodell, Miss. Bul. 242; Quesenberry, U.S.D.A. Cir. 65; see also: Tillman, Singletary, Kidwell, and Bray, La., Jour. Anim. Sci., 10, 1951, pp. 936–946; Dyer and Weaver, Mo. Bul. 641; McComas, Douglas, and Southwell, U.S.D.A. Tech. Bul. 864.
93. Miller, Ferguson, Brannon, and Thorndyke, N.Y., mimeo. rpt.; see also: Henke, Work, and Burt, Hawaii Bul. 85; Jones, Jones, Hall, and Neal, Tex. Bul. 599.
94. Kidder and Beardsley, Fla. Bul. 493; Chapman, Kidder, and Plank, Fla. Bul. 531.
95. Baker and Jackson, Nebr., North Platte Prog. Rpt. 69.
96. Osland, Maynard, and Morton, Colo. Bul. 422; Beeson, Hickman, Bolin, Johnson, and Rinehart, Id. Buls. 239, 244; Singleton, Ensminger, and Heinemann, Wash. Bul. 469.
97. Stanley, Ariz. Bul. 198; Edwards and Massey, Ga. Bul. 184; Skinner and King, Ind. Buls. 183, 191, 430; Evvard, Culbertson, et al., Iowa, mimeo. rpts.; McCampbell and Winchester, Kan. Cir. 92; Snell and Bray, La. Rpt. 1931–33 and mimeo. rpts.; Peters, Minn. Bul. 300; Trowbridge, Mo. Bul. 223; Thalman, Nebr. Bul. 355; Gerlaugh, Ohio Bimo. Buls. 154, 159, 166, 173, 198, Ohio Bul. 463; see also: Guilbert, Cal. Bul. 481; Kidder and Kirk, Fla. Bul. 360; Rusk and Snapp, Ill. Rpt. 1938; Webb and Bull, Ill. Bul. 510; Culbertson, Evvard, Hammond, and Bassett, Iowa Leaflet 27; Duitsman and Kessler, Kan. Cir. 322; Leinbach, Md. Bul. A-20; Trowbridge, Moffett, and Hazen, Mo. Bul. 413; Dickson, Mont. Bul. 359; Thalman, Nebr. Bul. 355; Pope, Bennett, Heller, and Campbell, Okla. Misc. Pub. MP-43; Ore. Cir. 137; Tomhave and Bentley, Penn. Bul. 183; Jacob, Tenn. Rpts. 1931, 1932, 1933; Jacob and Duncan, Tenn. Bul. 156; Burns, Tex. Bul. 110; Jones, Jones, Hall and Neal, Tex. Bul. 599; Hunt, Va. Rpt. 1920–27; Ensminger and Heinemann, Wash. Bul. 570; Fuller et al., Wis. Bul. 428; Hazen and Comfort, U.S.D.A. Tech. Bul. 862.
98. Skinner and King, Ind. Bul. 192.
99. Morton, Maynard, and Fairbanks, Colo. Press Bul. 76; Evvard, Culbertson, and Wallace, Iowa Bul. 215.
100. Bohstedt et al., Wis. Buls. 428, 430.
101. Richard et al., N.D. Bimo. Bul., 17, 1954, No. 1.
102. Maynard, Morton, and Osland, Colo. Bul. 379; Cox and Erhart, Kan. Cir. 250; Jordan and Peters, Minn. Bul. 306; Maynard, Esplin, and Boswell, Utah Bul. 238 and mimeo. rpt.; Hackedorn, Singleton, and Sotola, Wash. Bul. 351; Quayle, Wyo. Bul. 191; Ingraham, Wyo. Bul. 257; see also: Morton, Osland, and Tom, Colo. Press Buls. 91, 92; Johnson, Id. Buls. 244, 251; Cox and Sloan, Kan. Rpt. 1938–40; Bell, Ohio Bul. 497.
103. Snell and Taggart, La. Bul. 230.
104. Weiser and Zaitschek, Landw. Jahrb., 37, 1908, pp. 138–149.
105. Willett, Work, Henke, and Maruyama, Hawaii Tech. Bul. 3; see also: Sewell, Stringer, and Cullison, Ga., Jour. Anim. Sci., 13, 1954, pp. 998–999.
106. Carroll and Burroughs, Ill. Rpt. 1937; Aubel, Kan. Cir. 207; Snell, Upp, and Lush, La. Cir. 19; Loeffel, Nebr. Rpt. 1937; Robison, Ohio Bul. 607; Thompson, Okla. Rpt. 1936–38; Fargo, Bohstedt, and Lacey, Wis. Bul. 454; see also: Ferrin, Minn., mimeo. rpt.; Barnett and Goodell, Miss. Bul. 218; Fjeldsted and Potter, Ore. Bul. 165; Burns, Tex. Bul. 131; Hackedorn and Sotola, Wash. Bul. 169.
107. Rasmussen, Smith, Phillips, and Cunha, Utah Bul. 302.
108. Rice, Hawaii Bul. 67; Draper, Hawaii Rpt. 1942–44; Upp, La. Bul. 289; Norris and Heuser, N.Y. (Cornell) Rpt. 1935; Boucher,

Penn. Buls. 399, 414; Ott, Boucher, and Knandel, Penn., Poultry Sci., 21, 1942, pp. 340–345, 536–539.

109. Rosenberg, Hawaii Bul. 109; Rosenberg, Hawaii, Poultry Sci., 32, 1953, pp. 605–612; 33, 1954, pp. 382–389; Weeth and Rosenberg, Hawaii, Poultry Sci., 33, 1954, pp. 1135–1140.

110. Evvard, Culbertson, et al., Iowa, mimeo. rpts.; Skinner and King, Ind. Buls. 183, 191; Trowbridge, Mo., Amer. Soc. Anim. Prod., Proc. 1931, and mimeo. rpt.; Thalman, Nebr. Bul. 355; see also: Ky. Rpt. 1946.

111. Hudson, Mich. Quar. Bul., 16, 1933, No. 1.

112. Hickman, Rinehart, and Johnson, Id. Cir. 18; Gramlich, Nebr. Rpts, 1921, 1922, 1927, and mimeo. rpts.

113. Lindsey and Smith, Mass. Bul. 158; Hills, Vt. Bul. 171.

114. Madsen, Charkey, Manning, and Wilgus, Colo., Poultry Sci., 30, 1951, p. 935; Madsen, Colo., Poultry Sci., 31, 1952, p. 925.

115. Lofgreen, Meyer, and Weir, Cal. Agr., 6, 1952, No. 8; Lofgreen, Cal. Agr., 7, 1953, No. 7; Mead, Weber, and Dunkley, Cal. Agr., 7, 1953, No. 5.

116. Rosenberg, Hawaii Farm Sci., 1, 1952, No. 2; Rosenberg, Hawaii, Poultry Sci., 32, 1953, pp. 69–77; Palafox and Rosenberg, Hawaii, Poultry Sci., 33, 1954, pp. 127–133.

117. Henke, Hawaii, information to the author.

118. McCampbell, Kan. Bul. 186.

119. Wilcox et al., Utah Farm and Home Sci., 13, 1952, No. 2.

120. Lindsey, Mass. Rpt. 1913; Rothwell, Canada Expt. Farms, Anim. Husb. Div., Interim Rpt. 1922; see also: Grinnells, N.C. Rpt. 1938; Willard, Wyo. Rpts. 1935, 1942, 1943.

121. White and Johnson, Conn. (Storrs) Bul. 198; Billings, N.J. Bul. 189; Foster, N. Mex. Bul. 122; Monroe, Hayden, and Perkins, Ohio Bul. 470.

122. Woodward, Shepherd, and Graves, U.S.D.A. Misc. Pub. 130; Pratt, Va. Bul. 301; Henderson and Teague, West Va., Jour. Dairy Sci., 16, 1933, pp. 363–368.

123. Billings, N.J. Rpt. 1904; Lindsey, Mass. Rpt. 1913.

124. Connell et al., Colo. Farm. Bul., 6, 1944, No. 4; 7, 1945, No. 2; Connell, Colo. Farm and Home Res., 4, 1953, No. 1; Maynard, Morton, and Osland, Colo. Bul. 379; Johnson, Id. Bul. 251; Id. Bul. 269; Cox and Sloan, Kan. Rpt. 1938–40, Kan. Livestock Feeders' Day Rpts., 1947, 1948; Kiser, Christgau, and Peters, Minn., mimeo. rpt.; Dickson, Mont. Bul. 359; Clark, McCall, and Woodward, Mont. Cir. 184; Holden, Nebr. Bul. 194 and mimeo. rpt.; Baker, Reinmiller, and Baker, Nebr. Bul. 359; Baker and Baker, Nebr. Bul. 414; Maynard, Utah, mimeo. rpt.; Singleton, Ensminger, and Heinemann, Wash. Bul. 469; Quayle, Wyo. Bul. 191.

125. Maynard, Beets and Meat, Rev. Ed., 1950.

126. Harris, information to the author.

127. Holden, Nebr. Buls. 194, 216, 268; Quayle, Wyo. Bul. 191; see also: Miller, Cal., mimeo. rpt.

128. Dickson and Barnum, Mont. Bul. 312; Baker, Nebr. Bul. 350.

129. Ore. Bul. 461.

130. Woodman, Jour. Min. Agr. (Great Britain), 50, 1943, pp. 415–416; Woodman and Evans, Jour. Agr. Sci., England, 33, 1943, pp. 155–168.

131. Osland, Maynard, and Morton, Colo. Bul. 422.

132. Madsen and Nielsen, Utah, North Amer. Vet., 21, 1940, pp. 81–89, Utah Buls. 294, 306, 315; Maynard and Greaves, Utah Bul. 250.

133. Clark, Utah Bul. 101.

134. Bateman and Caine, Utah Bul. 239.

135. Maynard and Greaves, Utah Buls. 235, 250.

136. Osland, Maynard, and Morton, Colo. Bul. 422.

137. Hoffman and Bogart, Ore. Bul. 479.

138. Maynard, Morton, and Osland, Colo. Bul. 379; Maynard, Morton, and Fairbanks, Colo. Press Bul. 76; Hickman, Rinehart, and Johnson, Id. Cir. 40; Johnson, Rinehart, and Hickman, Id. Buls. 239, 244, 251, 268; Vinke, Bergstedt, and Hansen, Mont. Cir. 29 and mimeo. rpts.; Aune, S.D. Rpts. 1938, 1939, 1941; Ingraham, Wyo. Bul. 257; Quayle and Paules, Wyo. Cir. 44.

139. Osland, Maynard, and Morton, Colo. Bul. 422; Johnson, Id. Cir. 94; Carroll, Utah Bul. 192; see also: Esplin and Connell, Colo. Farm Bul., 8, 1946, No. 2.

140. Ky. Rpt. 1949; Drown and Forbes, Ky., Jour. Anim. Sci., 9, 1950, pp. 20–22; Dowe and Arthaud, Nebr. Rpt. 63; Lindahl, Davis, and Ellis, U.S.D.A., Proc. 5th Distillers Feed Conf., 1950.

141. Loosli, Turk, and Morrison, N.Y., Jour. Dairy Sci., 35, 1952, pp. 868–873; Loosli and Warner, N.Y., Jour. Dairy Sci., 36, 1953, pp. 1135–1139; Loosli and Warner, N.Y., Proc. 9th Distillers Feed Conf., 1954; Warner, Loosli, and Davis, N.Y., Proc. 10th Distillers Feed Conf., 1955; see also: Lindsey, Mass. Bul. 94; Hills, Vt. Rpt. 1907.

142. Ky. Rpts. 1949, 1950; Dowe and Arthaud, Nebr. Rpt. 63.

143. Klosterman and Bentley, Ohio An. Sci. Mimeo. 94; Ky. Rpt. 1941.

144. Aicher and Kessler, Kan. Cir. 292.

145. Garrigus, Ky., Proc. 8th Distillers Feed Conf., 1953; Ky. Rpts. 1951, 1952.

146. Leinbach, Md. Bul. A-20.

147. Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834.

148. Outhouse, Leinbach, and Meade, Md. Bul. A-32.

149. Tomhave, Del. Buls. 205, 207, 214, 220; Good and Smith, Ky. Bul. 190.

150. Robison, Ohio Bul. 607.

151. Wilcke and Thomas, Iowa Rpts. 1939, Part 1; 1940, Part 1; Parkhurst et al., Mass. Bul. 417; Parkhurst and Kuzmeski, Mass., Poultry Sci., 25, 1946, pp. 162–172; Sloan, Minn., Poultry Sci., 20, 1941, pp. 83–96; Mussehl, Sandstedt, and Ham, Nebr. Bul. 371; Wilson and Moxon, S.D. Rpt. 1944.

152. Buckner, Insko, and Harms, Ky. Bul. 423.

153. Hauge and Hughes, Ind. Rpt. 1943; Wilford, Garrigus and Barnhart, Ky. Bul. 577.

154. Runnels, Del., Proc. 10th Distillers Feed Conf., 1955; Scott, Ill., Proc. 10th Distillers Feed Conf. 1955; Novak and Hauge, Ind., Jour. Biol. Chem., 174, 1948, pp. 647–651; Norris, N.Y., Proc. 10th Distillers Feed Conf., 1955; Sunde, Cravens, Elvehjem, and Halpin, Poultry Sci., Wis., 29, 1950, p. 627.

155. Scott, Ill., Proc. 10th Distillers Feed Conf., 1955; Carrick, Roberts, Hauge, et al., Ind. Rpts. 1942, 1943, 1944, 1945, 1949; Parkhurst, Fellers, and Kuzmeski, Mass., Poultry Sci., 24, 1945, pp. 8–19; Morgan, S.C., Proc. 10th Distillers Feed Conf., 1955; Couch et al., Texas, Proc. 10th Distillers Feed Conf., 1955.

156. Catron et al., Iowa, Proc. 10th Distillers Feed Conf., 1955.

157. Robison, Ohio Res. Bul. 699; see also: Aubel,

Kan. Cir. 273; Kan. Rpt. 1948–50; Hanson, Baker, Baker, and Rumery, Nebr. Bul. 415; Willman and Morrison, N.Y. (Cornell) Bul. 836.
158. Krider, Fairbanks, and Carroll, Ill., Jour. Anim. Sci., 3, 1944, pp. 107–119; Fairbanks, Krider, and Carroll, Ill., Jour. Anim. Sci., 3, 1944, pp. 29–40; 4, 1945, pp. 410–419.
159. Bohstedt, Grummer, and Ross, Wis. Bul. 463.
160. Wilford, Garrigus, and Barnhart, Ky. Bul. 577; Hanson, Baker, Baker, and Rumery, Nebr. Bul. 415.
161. Elliott, Seath, and Bastin, Ky., Jour. Dairy Sci., 34, 1951, p. 505; Lassiter et al., Ky. Bul. 623; Huffman, Noller, and Williams, Mich., Proc. 9th Distillers Feed Conf., 1954; Morrow, Keener, and Teeri, N.H. Bul. 363; Slack and Turk, N.Y. Jour. Dairy Sci., 34, 1951, p. 505; Krauss, Monroe, Hibbs, and Pounden, Ohio Bul. 674; Schabinger and Knodt, Penn., Jour. Anim. Sci., 7, 1948, pp. 434–439; Williams and Knodt, Penn., Jour. Dairy Sci., 33, 1950, pp. 809–814.
162. Loosli, Turk, and Morrison, N.Y., Jour. Dairy Sci., 35, 1952, pp. 868–873; Loosli and Warner, N.Y., Jour. Dairy Sci., 36, 1953, pp. 1135–1139.
163. Garrigus, Ky. Bul. 564.
164. Black, Ellis, and Garrigus, U.S.D.A. and Ky., Jour. Anim. Sci., 4, 1945, pp. 158–163; see also: Ky. Rpt. 1944; Leinbach, Md. Bul. A-20.
165. Turk and Berry, Md., Jour. Dairy Sci., 23, 1940, pp. 560–561.
166. Wilford, Ky. Rpts. 1935, 1936, 1937.
167. Insko, Ky. Cir. 46.
168. Baker, N.Y., Cornell Vet., 31, 1941, pp. 13–16.
169. Barton, Ness, and Crampton, Macdonald Col., McGill Univ., Canada, Tech. Bul. 3.
170. Henke, Hawaii Bul. 95.
171. Temperton and Dudley, Harper Adams Util. Poultry Jour., England, 26, 1941, pp. 172–173; Richter, Bunger, et al., Biedermann's Zentbl., Abt. B, Tierernähr., 8, 1936, pp. 594–607.
172. Braude and Kon, England, Jour. Compar. Pathol. and Ther., 54, 1944, pp. 88–96.
173. Sure, Ark. Bul. 493.
174. N.H. Bul. 372.
175. Ritzman, N.H. Engin. Sta., Pub. 7; see also: Vedvik, Cravens, and Sunde, Wis. Bul. 509; Morimoto et al., Japan, Bul. Nat. Inst. Agr. Sci., G, 1954, No. 9, pp. 133–140.
176. Diamond, Secretary, Amer. Feed Manufacturers Assoc., information to the author; see also: Wherry. The Golden Anniversary of Scientific Feeding, 1947.
177. Richardson and Halick, Tex. Bul. 754; Halick and Richardson, Tex. Bul. 768; Richardson and Halick, Tex., Jour. Anim. Sci., 12, 1953, pp. 929–930.
178. Reid, Warner, and Loosli, N.Y., Antibiotics in the Nutrition of Ruminants, Jour. Agr. and Food Chem., 2, 1954, pp. 186–192; Lassiter, Ky., Antibiotics as Growth Stimulants for Dairy Cattle, Jour. Dairy Sci., 38, 1954, pp. 1102–1138; Braude, Wallace, and Cunha, Fla., The Value of Antibiotics in the Nutrition of Swine, Antibiotics and Chemotherapy, 3, 1953, pp. 271–291; Braude, Kon, and Porter, England, Nutr. Abstracts and Reviews, 23, 1953, pp. 473–495; Stokstad, Antibiotics in Animal Nutrition, Physiol. Reviews, 34, 1954, pp. 25–51.
179. Coates et al., England, cited by Braude, [illegible] Abstracts and Reviews, 23, 1953, p. [illegible].
180. Libby and Schaible, Mich., Science, 121, 1955, pp. 733–734; Waibel, Abbott, Baumann, and Bird, Wis., Poultry Sci., 33, 1954, pp. 1141–1146.
181. Bucy et al., Ill., Jour. Anim. Sci., 13, 1954, pp. 668–676.
182. Pratt and Holdaway, Va. Bul. 326.
183. Hackedorn, Singleton, and Sotola, Wash. Buls. 291, 351.
184. Knott, Murer, Hodgson, and Overholser, Wash. Bul. 362.
185. Heinemann, Wash. Sta. Cir. 84.
186. Gordon, Cal. Leaflet 7.
187. Clark, Utah Bul. 101.
188. Kirk, Felton, Fulford, and Hodges, Fla. Bul. 454.
189. Kirk, Hodges, and Kelly, Fla. Rpt. 1950.
190. Cunha et al., Fla. Cir. S-11.
191. Ariz. Rpt. 19.
192. Henke, Willett, and Maruyama, Hawaii [illegible] Rpt. 45.
193. Squibb and Salazar, Guatemala, Jour. Anim. Sci., 10, 1951, pp. 545–550.
194. Bice, Hawaii Cir. 4.
195. Atkeson and Anderson, Id. Bul. 150; Lindsey, Mass. Rpt. 1905; Hills, Vt. Rpt. 1903; see also: Perkins and Monroe, Ohio Bimo. Bul. 175.
196. Lindsey, Beals, and Archibald, Mass. Bul. 205; Holdaway, Va. Bul. 243; Knott, Hodgson, and Ellington, Wash. Bul. 270; see also: Walton and Bidwell, U.S.D.A. Bul. 1166.
197. Heinemann, Ensminger, and Ham, Wash. Bul. 543.
198. Woodward et al., U.S.D.A. Bul. 1272.
199. Grimes, Penn. Buls. 215, 230.
200. Henke, Hawaii Bul. 6; de Alba, Garcia, Perez Cano, and Ulloa, Costa Rica, Turrialba, 4, 1954, pp. 29–34.
201. Klein and Barlöwen, Germany, Arch. Geflügelk., 18, 1954, pp. 415–428.
202. Noland, Brown, and Baugus, Ark. Farm Res., 4, 1955, No. 2; Noland, Ford, and Ray, Ark., Jour. Anim. Sci., 14, 1955, pp. 860–865.
203. Dix Arnold, Becker, and Neal, Fla. Bul. 354.
204. Ga. Rpt. 1938; Archibald, Mass. Bul. 355; Garrett, Arnold, and Hartman, N.J., Jour. Dairy Sci., 24, 1941, pp. 71–83.
205. Copeland and Shepardson, Tex. Bul. 658; see also: Faires, Van Horn, Dawson, and Waugh, U.S.D.A. Cir. 811.
206. Kemmerer, Harland, and Davis, Ariz. Bul. 218.
207. Cal. Agr., 5, 1951, No. 6; Becker and Dix Arnold, Fla. Cir. S-40.
208. Kemmerer, Harland, and Davis, Ariz. Bul. 218; Ariz. Rpt. 1951.
209. Ariz. Rpts. 1949, 1950.
210. Kirk, Felton, Fulford, and Hodges, Fla., Bul. 454; Peacock and Kirk, Fla., Jour. Anim. Sci., 14, 1955, p. 1120; Jones, Hall, Neal, and Jones, Tex. Bul. 613; Tex. Bul. 724.
211. Chapman, Kidder, and Plank, Fla. Bul. 531.
212. Crown, Kirk, and Neal, Fla. Rpts. 1938, 1939.
213. Cal. Rpt. 1936–38; Mehrhof and Rusoff, Fla. Rpts. 1938, 1939; Driggers, Davis, and Mehrhof, Fla. Rpt. 1947.
214. Wallace, Combs, and Cunha, Fla. Rpt. 1953.
215. Becker, Davis, Kirk, Dix Arnold, and Hayman, Fla. Bul. 423; Stanley, Ariz. Bul. 198; Ariz. Rpt. 1942.
216. Baker, Fla. Cir. S-22; Baker, Fla. Rpt. 1953; Chapman, Kidder, and Plank, Fla. Bul. 531; Texas Bul. 724.

217. Cunha et al., Fla. Rpts. 1949, 1950, 1952.
218. Driggers and Mehrhof, Fla. Rpts. 1951, 1952.
219. Driggers, Davis, and Mehrhof, Fla. Bul. 476; Glasscock et al., Fla. Cir. S-12.
220. Ashbrook and Wilson, U.S.D.A., Farmer's Bul. 1133; Stanley, Bell, and Rigden, Ariz. Bul. 185; Sullivan, Maharg, and Hughes, Cal. Exten. Cir. 166; Willett et al., Hawaii Tech. Bul. 7; Ky. Rpt. 1918; Allen, Md. Bul. 227; Ensminger, Mass. Exten. Leaflet 188; Miss. Bul. 218; N.J. Rpt. 1945; Robison, Ohio Bul. 607; Thompson, Okla. Rpt. 1919; Ore. Bul. 359; Hultz and Reeve, Wyo. Bul. 135.
221. Willett et al., Hawaii Tech. Bul. 7.
222. Vestal, Ind., mimeo. rpt.; Evvard, Culbertson, et al., Iowa Leaflet 6; Weaver, Mo. Bul. 247.
223. Harper, Ind. Bul. 470.
224. Henke, Hawaii Bul. 95; Draper, Hawaii Progress Notes 42.
225. Tomhave and Hoffman, Del. Bul. 251; Willman, McCay, Salmon, and Krider, N.Y., Jour. Anim. Sci., 1, 1942, pp. 38–40.
226. Cunha, Lindley, and Ensminger, Wash., Jour. Anim. Sci., 5, 1946, pp. 219–225.
227. Kempster, Mo., Poultry Sci., 24, 1945, pp. 396–398; Kennard and Chamberlin, Ohio Bimo. Bul. 228; Halpin, Holmes, and Meshew, Wis. Bul. 443; Hammond, Fritz, Nestler, and Titus, Poultry Sci., 23, 1944, pp. 217–220.
228. Vestal, Ind. Bul. 413; Shrewsbury and Vestal, Ind. Bul. 489; Berry and Turk, Md., Jour. Dairy Sci., 27, 1944, pp. 861–866; Hostetler, N.C., information to the author; Monroe, Bachtell, and Hayden, Ohio Bimo. Bul. 178; Monroe and Bachtell, Ohio Buls. 497, 532; Robison, Ohio Spec. Cirs. 32, 39; Ikeler, Utah, mimeo. rpt.; Miller and Bearse, Wash., Poultry Sci., 15, 1936, pp. 19–22; Schultze, Elvehjem, Hart, and Halpin, Wis. Bul. 435; MacIntyre and Jenkins, Canada, Sc. Agr., 32, 1952, pp. 559–567.
229. Embleton, Ariz. Rpts. 1932, 1933; McCrary and Taylor, Mich. Quar. Bul., 26, 1944, No. 3; Freeman and Brown, Mich. Quar. Bul., 26, 1944, No. 3; Card, Mich., information to the author; Bartlett, N.J. Rpts. 1930, 1931; N.J. Rpts. 1937, 1938, 1939; Skelley, N.J. Rpt. 1931; Monroe and Mahan, Ohio Bimo. Bul. 155; Monroe, Krauss, and Hayden, Ohio Bimo. Bul. 174; Miller and Bearse, Wash., Poultry Sci., 15, 1936, pp. 19–22; Clark, West Va., information to the author.
230. Burt, Bartlett, and Rowland, England, Jour. Dairy Res., 21, 1954, p. 299.
231. Cameron, Canadian Jour. Sci. Agr., 34, 1954, pp. 181–186.
232. MacIntyre, Canadian Jour. Sci. Agr., 35, 1955, pp. 168–174.
233. Raimonde, Riv. Zootec., 14, 1937, pp. 77–84, 114–116, 119–125.
234. Anderson, Cal., mimeo. rpts.
235. Jones, Ore. Cir. of Inf. 430.
236. Guilbert and Weir, Cal. Agr., 5, 1951, No. 11.
237. Murdock, Hodgson, Blosser, and Shaw, Wash., Jour. Dairy Sci., 35, 1952, p. 503.
238. Henke, Hawaii Cir. 2; Henke and Goo, Hawaii Sta., Anim. Husb. Div. Progress Notes No. 13; Henke, Work, and Burt, Hawaii Bul. 85; see also: Becker, Davis, Dix Arnold, and Marshall, Fla. Rpt. 1950.
239. Dickey, Highlands, and Getchell, Me. Bul. 491; Dickey, Me. Bul. 483; Turk, N.Y., information to the author.
240. Wokes, Still, and Organ, Jour. Min. Agr., Great Britain, 49, 1942, pp. 18–21.
241. Stanley, Ariz. Bul. 198; Connell, Tom, and Wheeler, Colo. Tech. Bul. 37; Johnson, Id. Bul. 251; Harris, Nebr. Rpt. 59.
242. Ariz. Rpt. 1945; Hughes and Heitman, Cal. Bul. 709; Connell, Tom, and Wheeler, Colo. Tech. Bul. 37; Gerry, Me. Bul. 535; McMillin, Brown, and Luecke, Mich. Quar. Bul., 30, 1948, No. 4; Heuser, Scott, and Norris, N.Y. (Cornell) Rpt. 1948; Heuser, Scott, Eskew, and Edwards, N.Y., Poultry Sci., 30, 1951, pp. 672–678; Longwell and Buchanan, N.D. Bimo. Bul., 7, 1945, No. 6; Woodman and Evans, Jour. Agr. Sci., England, 33, 1943, pp. 1–14.
243. Dickey, Me. Farm Res., 2, 1955, No. 4; Dickey, Me. Bul. 539.
244. Gerry, Me. Bul. 535; see also: Fangauf, Germany, Archiv. Geflügelk, 17, 1952, pp. 27–29.
245. Miller, Cal. Bul. 431.
246. Kratzer and Williams, Cal. Agr., 5, 1951, No. 4.
247. Hughes and Ittner, Cal. Exten. Cir. 15; Folger, Cal. Bul. 635; Ore. Bul. 401.
248. Miller, Cal. Bul. 431.
249. Folger, Cal. Bul. 635; Willman and Morrison, N.Y. (Cornell) Sta., unpublished data.
250. Adams et al., Ill. Jour. Anim. Sci., 14, 1955, pp. 1191–1192.
251. Firth and Johnson, Ill., Jour. Agr. and Food Chem., 3, 1955, pp. 795–796.
252. Briggs et al., Okla. Tech. Bul. T-28.
253. Frye, Thomason, and Henderson, Ga., Jour. Dairy Sci., 31, 1948, pp. 341–346; Frye, Hawkins, and Henderson, Ga., Jour. Dairy Sci., 31, 1948, pp. 897–903; Massey, Denny, and Southwell, Ga. Cir. 156; Henke and Morita, Hawaii Rpt. 1948–50; Seath, Rusoff, Miller, and Branton, La. Bul. 423; Grinnells, Moore, Waugh, and Colvard, N.C. Res. in Farming, 8, 1950, No. 4; Lease and Mitchell, S.C. Bul. 329; Copeland, Tex. Rpt. 1941; Mather, Linkous, and Eheart, Va., Jour. Dairy Sci., 31, 1948, pp. 569–576.
254. Grimes, Ala. Rpts. 1941, 1942; Kidder, Fla. Bul. 456; Ga. Coastal Plain Bul. 45; Singletary, McCraine, and Berwick, La. Bul. 446; Cullison, Miss. Farm Res., 5, 1942, No. 7; Darlow et al., Okla. Bul. B-342; Duncan, Tenn. Rpt. 1942; Tex. Bul. 724.
255. Massey and Buice, Ga. Bul. 236.
256. Grimes, Ala. Rpt. 1941; Ga. Coastal Plain Bul. 36; Singletary, La., Jour. Anim. Sci., 7, 1948, p. 533; Bedenbaugh, Miss. Farm Res., 5, 1942, No. 7; N.C. Rpt. 1943; Thompson, Okla. Bul. 296; Godbey, Mitchell, and Starkey, S.C. Rpt. 1947.
257. Driggers, Mehrhof, and Davis, Fla. Rpt. 1948; Tillman and Davis, La. Bul. 358; Miss. Rpt. 1943; Dearstyne, Peterson and Nesbit, N.C. Res. and Farming, 3, 1944, No. 1.
258. Tomhave, Del. Buls. 172, 179; Hays, Del. Bul. 124.

CHAPTER XXIV

MANURIAL VALUE OF FEEDING STUFFS

985. Importance of manure in maintaining fertility.—One of the great advantages of livestock farming is that the use of farm manure makes possible the maintaining and building up of soil fertility at minimum expense. Unless the plant food removed by the growth of crops is returned in some form, the land will sooner or later become so poor that profitable crops cannot be grown.

When proper use is made of farm manure, most of the plant food contained in the crops fed to stock is returned to the fields. If, in addition, legumes are grown regularly in the crop rotation to help in supplying nitrogen, the soil fertility can then be built up with but minimum use of commercial fertilizers.

986. Farm manure as a fertilizer.—Farm manure, like commercial fertilizers, is valued chiefly on the basis of the nitrogen, phosphorus, and potassium it contains. These fertilizing constituents and calcium are the only plant foods that ordinarily need be replaced of those which are removed from the soil by crops.

In addition to the amounts of plant food it furnishes, farm manure also has other beneficial effects. The large quantities of organic matter it contains add to the humus content of the soil, thus increasing its water-holding capacity, improving the texture, and making it more resistant to wind action. In the decay of the organic matter, acids are formed that help to dissolve plant food in the soil that would otherwise be insoluble. A good supply of organic matter in the soil is so important that when farm manure is not available, special green manuring crops are often grown and plowed under, solely to furnish organic matter.

Manure also has a beneficial effect because of the great numbers of various kinds of bacteria that it contains. These cause chemical changes not only in the manure but also in the soil itself, changing insoluble plant food into forms available to crops.

Experiments have shown that the fertilizing constituents present in manure when it is applied to the land have fully as high a value as those in high-grade commercial fertilizers. The cost of nitrogen, phosphorus, and potassium in commercial fertilizers varies considerably, depending on the type of fertilizer and the section of the country. In this chapter the following prices are used in computing the fertilizing values of feeds and farm manures: Nitrogen, 15 cents per pound; phosphoric acid, 10 cents per pound; and potash, 5 cents per pound.

The amount of phosphorus in a commercial fertilizer is commonly expressed in terms of *phosphoric acid* (P_2O_5), instead of *phosphorus* (P). On the other hand, in animal nutrition and livestock feeding, the amount of the mineral is now generally expressed as *phosphorus*. Similarly, the amount of potassium in fertilizers is usually expressed in terms of *potash* (K_2O), instead of *potassium* (K).

The preceding prices for phosphoric acid and potash are equivalent to 22.9 cents per pound for phosphorus and 6.0 cents per pound for potassium.

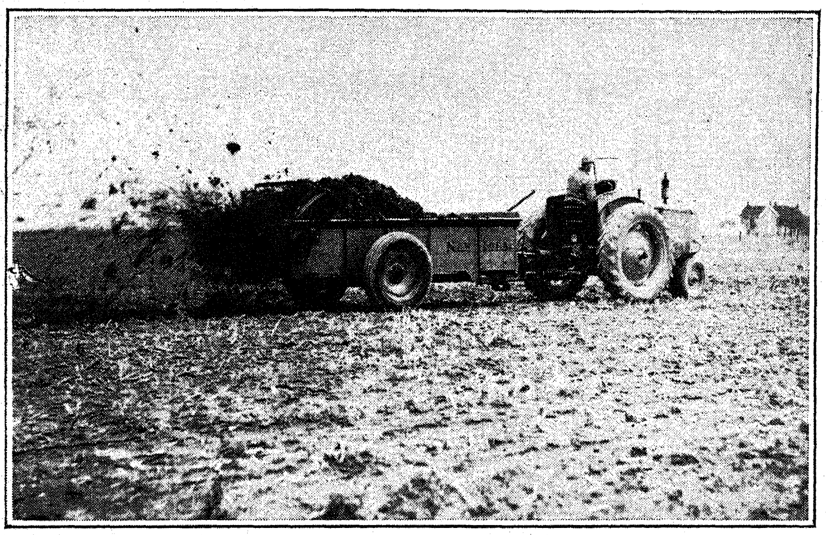
987. Fertilizing constituents recovered in manure.—The fertilizing constituents in manure come entirely from the feed consumed, for an animal creates no fertility value. It merely excretes in the feces and urine a greater or less percentage of the nitrogen, phosphorus, and potassium that is contained in the feed it eats. The value of the manure therefore depends, first of all, on the kind of feed the animal gets. Only feeds rich in fertilizing constituents make rich manure.

The proportion recovered in the manure of the fertilizing constituents that the feed contains, depends on the age

kind of animal. A mature animal (such as a work horse) which is not gaining in weight and which is not pregnant or producing milk, will excrete in feces and urine all the fertilizing constituents in its feed, with the exception of the nitrogen used in the growth of hair or wool and the small amounts of fertilizing constituents contained in the sweat. Therefore such an animal will excrete in feces and urine practically all the nitrogen, phosphorus, and potassium there is in its ration.

On the other hand, a young growing animal in building its body will store a considerable proportion of the fertilizing constituents there are in its feed. A calf a few weeks old may store fully two-thirds of the nitrogen and mineral matter there are in the milk and other feed it consumes. As an animal grows older, the proportion of the nitrogen and mineral matter that is stored in growth rapidly decreases, and the proportion excreted in the manure correspondingly increases. Thus, 5-month-old calves will excrete in the manure about 70 to 80 per cent of the nitrogen in their feed, and 2-year-old fattening steers about 87 per cent.[1]

Because of the richness of milk in nitrogen and in phosphorus, when dairy cows producing a good yield of milk are fed the usual types of rations they will excrete in feces and urine only about 70 per cent of the nitrogen in their ration and 63 per cent of the phosphorus.[2] The proportion of potassium is considerably higher, being about 86 per cent.



Saving the Fertility in Feeding Stuffs

If possible, the manure should be drawn directly to the field and spread each day. However, this is not advisable on sloping land in winter when there is deep snow on the fields. (From New Idea Farm Equipment Company.)

Considering the proportion of the various classes and ages of animals on the average general farm, probably about 80 per cent of the fertilizing value of all the feed consumed is excreted in the feces and urine. On dairy farms, where most of the animals are cows in milk, the percentage will be somewhat lower.

988. Fertility and manurial value of feeds.—In buying or selling feeds, too few farmers consider their value as fertilizers as well as the feeding value. The amounts of fertilizing constituents in the important feeds are given in Appendix Table I. To bring out certain points, there are presented in the following table

these data for a few typical feeds and also data for certain animal products. The fertility value of each has been computed at the prices for nitrogen, phosphorus, and potassium given previously.

The last column gives the average manurial value of the various feeds. This has been computed on the assumption that when proper care is taken of the manure, there can be recovered in the manure for application on the land an average of 70 per cent of the phosphorus and potassium and 50 per cent of the nitrogen contained in the feed. These estimates take into consideration the fact that some losses of fertilizing constituents, especially of nitrogen, occur in the storage and application of manure, even when the precautions are taken which are mentioned later. Obviously, these manurial values hold good only when the manure is handled properly.

The table shows that the fertility value of corn grain is $5.76 per ton. This means that the nitrogen, phosphorus, and potassium removed from the soil in [illegible] ton of corn would cost about $5.[illegible] if bought in commercial fertilizers. The manurial value of corn grain is $3.20 per ton, which means that the manure resulting from feeding a ton of the grain to stock will, on the average, supply about $3.20 worth of fertilizing constituents, if proper care is taken of the manure.

Fertilizing constituents in feeds and in animal products

	Fertilizing constituents			Fertility value per ton	Manurial value per ton
	Nitrogen	Phosphorus	Potassium		
	Per cent	Per cent	Per cent	Dollars	Dollars
Concentrates					
Corn, dent, No. 2	1.39	0.27	0.29	5.76	3.20
Oats	1.92	0.33	0.43	7.79	4.[illegible]
Barley	2.03	0.40	0.49	8.51	4.74
Wheat bran	2.62	1.29	1.23	15.24	9.10
Soybeans	6.06	0.59	1.50	22.68	12.24
Linseed meal	5.63	0.86	1.24	22.32	12.24
Cottonseed meal, 41% protein	6.66	1.11	1.48	26.84	14.79
Tankage, digester, 60% protein	9.50	3.23	0.46	43.85	24.99
Roughages					
Alfalfa hay	2.45	0.24	1.97	10.81	6.10
Clover hay, red	1.92	0.20	1.65	8.66	4.91
Timothy hay	1.06	0.14	1.59	5.73	3.38
Oat straw	0.66	0.09	2.00	4.79	2.96
Corn silage, well matured	0.37	0.07	0.30	1.79	1.03
Animal products					
Fat steer	2.56	0.59	0.14	10.55	....
Fat pig	2.32	0.37	0.13	8.81	....
Milk	0.56	0.10	0.14	2.31	....
Butter	0.14	0.02	0.01	0.52	....

The fertility values and the manurial values are somewhat higher for oats and barley than for corn, because these grains contain more nitrogen, phosphorus, and potassium than does corn. The values for the protein-rich feeds, such as soybeans, linseed meal, cottonseed meal, and tankage, are high, because of their richness in nitrogen and also in minerals. If legume crops, such as soybeans, are properly inoculated, the amount of fertility removed from the soil is much less than indicated by the fertility value of the crop. This is because most of the nitrogen will have been secured indirectly from the air, instead of from the soil.

When such protein-rich feeds as cottonseed meal, linseed meal, and tankage are purchased and fed to stock and proper care is taken of the manure produced, a double return is secured. The first return comes from the high feeding value of these protein supplements, and the second comes from the fertility added to the soil.

The fertility value of legume hay is much greater than that of grass hay, because of its richness in protein. It is important to note that when the hay is fed to stock and proper care is taken of the manure, each ton of red clover hay will add [illegible] worth of plant food to the soil and each ton of alfalfa hay, $6.10.

989. Selling fertility.—The preceding table also shows that farmers who sell such crops as hay, corn, and wheat, part with more fertility for a given sum than do those who sell animals or their produce. The farmer who sells 1,000 lbs. of clover hay, worth $10 to $12, parts with about as much fertility as if he had sold 1,000 lbs. of fat cattle or pigs, worth 10 to 20 times as much. Based on the selling price, milk carries considerable fertility from the farm and butter practically none.

The farmer who grows and sells grain, hay, and straw is selling a large amount of fertility, the need of which will surely be apparent as time goes on and his fields give smaller and smaller returns. Such a farmer is slowly but surely mining phosphorus and potassium from his soil, which can be replaced only by some purchased material.

In Great Britain, where many of the farmers are long-period tenants, the manurial value of feeding stuffs is recognized by law. When a tenant vacates his leasehold, he is paid for the manurial value of feeds which he has recently purchased and fed on the farm, and, under certain conditions, for the manurial value of grain produced on the farm and fed to stock. Similar provisions should be drafted into farm leases in this country.

990. Buying fertility in purchased feeds.—Even in livestock farming where little or no grain or roughage is sold and when proper care is taken of the manure, not all of the fertility in the crops is returned in the manure. The growth of legumes will aid in maintaining the nitrogen supply in the soil, but under actual conditions on most farms, supplying additional nitrogen in manure or fertilizer will increase crop yields.

Sooner or later in practically all cases it is necessary to replace the small but steady loss of phosphorus and potassium. In purchasing feeds, one should therefore consider not only their feeding value but also their worth as fertilizers. By a wise selection of purchased concentrates, the livestock farmer can build up the fertility of his farm without the use of any commercial fertilizers, except lime to correct soil acidity and probably phosphate to balance the farm manure, which is ordinarily much richer in nitrogen than in phosphorus.

To determine which feeds are the cheapest when consideration is given to the manurial value, one should deduct the manurial value per ton from the gross price.

For instance, in an example given in Chapter X of the method for determining which feeds are the cheapest sources of total digestible nutrients and of digestible protein, it was assumed that a dairyman had ground corn available on the farm at a price of $52.00 per ton. (388) Among the protein supplements he could purchase on his local market was cottonseed meal (41 per cent protein grade) at $70.00 per ton.

If we deduct the manurial value of cottonseed meal per ton (which is $14.79) from the purchase price the net cost per ton would be only $55.21 per ton. Similarly, deducting the manurial value of corn ($3.20 per ton) from the price, the net cost would be $48.80 per ton. Thus, at these prices the net cost of cottonseed meal is only $6.41 more per ton than that of corn, if proper credit is given for the difference in the manurial values of the two feeds.

991. Composition and value of fresh manure.—The value of farm manure produced by animals of the same kind varies rather widely, depending chiefly on the nature of the feed sup-

plied. However, it is desirable to have an approximate idea of its general composition.

Mixed fresh farm manure from dairy farms, including bedding, contains an average of 10 to 12 lbs. of nitrogen, 5 lbs. of phosphoric acid (equivalent to 2.2 lbs. of phosphorus), and 10 lbs. of potash (equivalent to 8.3 lbs. of potassium) per ton. With these fertilizing constituents at the prices stated previously, average farm manure has a value of $2.50 to $2.80 per ton.

The average composition of fresh manure (including bedding, except in the case of hen manure) for the various classes of farm stock is shown in the following table.[3] The last column shows the average value per ton of the various kinds of manure. The table also shows the composition of dry floor-litter hen manure, as accumulated in a laying house.

Average composition of manure from farm animals

	Water Per cent	Nitrogen Lbs. per ton	Phosphorus Lbs. per ton	Potassium Lbs. per ton	Value Dollars per ton
Dairy cows	79	10.7	2.1	9.4	2.65
Fattening cattle	78	14.6	4.2	9.2	3.70
Sheep	64	21.5	6.3	22.0	5.99
Horses	59	14.0	2.2	12.8	3.37
Swine	74	9.8	3.0	7.8	2.63
Hens (without litter)	76	22.6	7.6	7.6	5.59
Hens (dry floor-litter manure)	25	45.2	22.8	20.4	13.23

The manure from horses, sheep, and hens is much drier than that from cattle or swine, and therefore is especially apt to heat unduly in storage, on account of rapid fermentation. These manures are often called "hot manures," in contrast to manures from cattle and swine, which are termed "cold manures."

992. Manure produced yearly.— The amount of manure (including bedding) produced yearly by any class of stock will vary considerably, depending chiefly on the liberality of feeding and the amount of bedding. When all the manure is saved, approximately the following amounts of manure, including bedding, are produced per 1,000 lbs. live weight by the various classes of stock:[4] Dairy cows, 15 tons; fattening cattle, 8.5 tons; sheep, 7.5 tons; horses, 9 tons; swine, 18 tons; and poultry, only [illegible] tons.

Under usual farm conditions much of the manure is not voided in the stable. That which is excreted by stock on pasture or by horses working in the fields is commonly well utilized, but a considerable loss occurs through the amounts voided in exercise paddocks or by horses on the road.

In Ohio studies it was estimated that the following amounts of manure, ready for field application, were produced *per head* by farm animals in a year, excluding that voided while the animals were in the yards or at work:[5] Horses, 6.0 tons; fattening cattle, 7.8 tons; sheep, 0.75 ton; and hogs, 1.7 tons.

In studies on Illinois dairy farms it was found that 6.6 loads of manure (including bedding) were actually recovered annually per mature cattle unit.[6] For work horses and mules the amount actually hauled to the fields was 5.45 loads per head annually.

In other Illinois studies when beef cattle were fattened in paved feed lots with adjacent sheds, the amount of manure recovered per head was 0.23 to 0.30 ton per month for fattening calves and 0.45 to 0.51 ton per month for yearlings.[7]

993. Importance of saving urine.— In preventing losses of fertilizing value in farm manure, one of the most important points is to use sufficient bedding to absorb the urine. In the case of cattle and sheep, the urine may contain fully one-half of the nitrogen in the total excrement and three-fourths of the potassium.[8] Even for horses and swine, one-third of the nitrogen and two-fifths of the potassium are in the urine. Practically

all of the phosphorus and calcium is in the feces except in the case of swine, which excrete about 12 per cent of the phosphorus in the urine.

Pound for pound, the urine has a greater fertilizing value than the feces, except with swine, whose urine is large in quantity, and watery. The fertilizing constituents in the urine are also in solution, hence much more readily available to plants than those in the feces. The feces consist chiefly of food residues which were too insoluble to be digested.

It is obvious that much fertility is lost if the urine drains away from the stable, because of insufficient bedding and gutters that are not water-tight. Also, there is usually a heavy loss of fertility in exercise paddocks.

994. Bedding, or litter.—Bedding, or litter, not only keeps stabled animals clean and comfortable, but it is also very important to absorb the urine. In addition, it increases the content of organic matter, it may supply significant amounts of plant food, and it makes the manure easier to handle.

Straw is the most common bedding material on most stock farms. If it is not too coarse, straw will absorb 2 to 3 times its weight of water, or even more.[9] Unless straw is very coarse, as is the case with rye straw, chopping does not increase its water absorbing capacity very much. For bedding dairy cows, it may require a larger weight of cut straw than of long straw, as the latter stays in place better.[10] The amounts of fertilizing constituents in various kinds of straw are shown in Appendix Table I.

From 4 to 8 lbs. of straw per head daily are usually sufficient for dairy cows in stanchions, if the platforms are of the proper length. Considerably more is needed when cows are housed in a loose stable. (1089) In Illinois tests 4 to 5 lbs. per head daily of straw were needed for 1,000-lb. fattening steers which were fed in open sheds that were cleaned once a month.[11] Twice as much was needed when cattle were kept in single stalls that were well-bedded and cleaned once a day.

When stock are fed *shredded* or *cut dry corn* or *sorghum stover* or *fodder*, the coarser parts that are refused make satisfactory bedding. If not needed for feed, finely-shredded stover makes excellent bedding, nearly equalling straw in water-absorbing capacity.

When these farm-produced bedding materials are not available, either *wood shavings* or *sawdust* are used most commonly as the substitute. These wood by-products, especially from hardwood, often have a somewhat lower absorptive capacity per pound than straw. Shavings and sawdust add very little fertility to manure, and they do not decompose rapidly in the soil. A much greater weight of shavings is required than of straw for bedding dairy cows. In Indiana tests more than twice the weight of shavings was needed.[12]

When manure contains a large amount of sawdust or shavings, or even of straw, in proportion to the amount of excrement, a temporary deficiency of available nitrogen may be produced in the soil. This is because much of the nitrogen in the manure is assimilated by soil bacteria in the decomposition of the material, and then converted into forms that are only slowly available to plants. This effect can be prevented by supplementing such manure with a readily-available nitrogen fertilizer. Except for this effect, the use of any ordinary amount of sawdust or shavings for bedding is not detrimental to crops.[13]

Portable machines have recently been developed by means of which waste limb wood or brush is chipped fine enough for bedding. Chipped wood was satisfactory bedding for dairy cows in Indiana and New York tests, but a greater weight was needed than of shavings.[14]

Ground corn cobs, ground in a hammer mill with a five-eighths inch screen, were satisfactory bedding for dairy cows in Indiana tests.[15] It required over 3 times the weight of ground cobs as of straw.

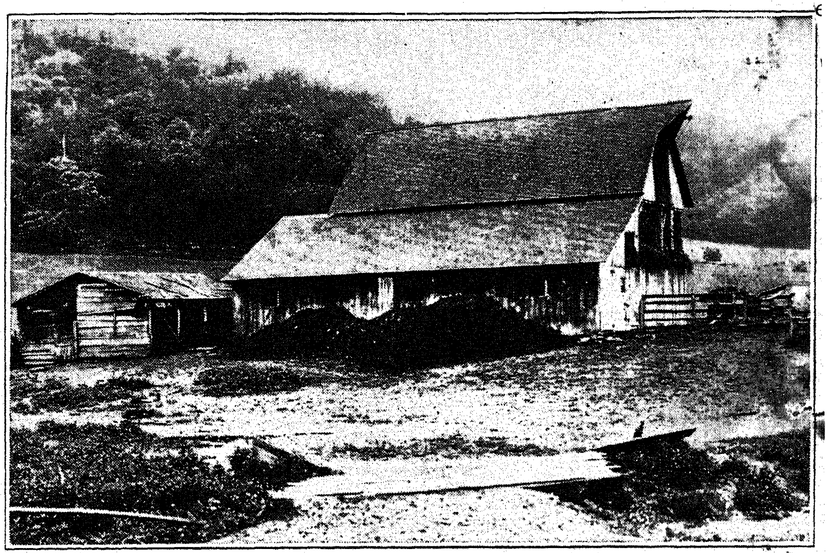
Dry *peat moss* absorbs 5 to 10 times its weight in water, is a good deodorant, and is excellent for bedding, but it is usually expensive. It is especially good

for calf pens. Cows may become stained if the same peat moss is used in the stall too long. Contrary to claims sometimes made, peat had no inhibiting effect on the development of flies in the manure in tests by the United States Department of Agriculture.[15]

Cocoa shells are sometimes used for bedding and have about the same absorbing capacity as straw.[16] They are a good deodorant but are difficult to keep in place in dairy stables, and they pack hard.

Peanut hulls, or shells, are sometimes used for bedding. The unground hulls have about the same water-absorbing capacity as sawdust or shavings. However, in dairy stables, peanut hulls do not stay under the cows so well as shavings or straw.[17] They are also inclined to stick to the hair on the udders. In the production of sanitary milk, cows bedded with peanut hulls may therefore require more brushing than those bedded with straw or shavings. In the summer, peanut hulls may attract flies, because of small amounts of fragments of oily peanut kernels still left in the h

Buckwheat hulls have ab the same absorptive capacity as shavi but they are rather hard to keep in p for dairy-cow bedding.[18] They son es lodge between the toes of cattle, s- ing infection. It is not safe to bed s with buckwheat hulls, for they ofte t them, which is apt to cause ind ge



Such Losses of Fertility Occur on Many Farms

When manure is loosely piled under the eaves, heavy losses of fertility occur through fermentation and leaching. Note that every hard rain will leach fertility from the manure pile to the ditch in the foreground. (From Wisconsin Station.)

Oat hulls may likewise be used for bedding, but they have the same disadvantages as buckwheat hulls and are dusty for use in dairy stables. They are excellent, however, as poultry litter.

995. Reducing the losses in farm manure.—In spite of the value of farm manure, many farmers who freely purchase commercial fertilizers allow much of the value of the manure produced by their livestock to be wasted. Manure is a perishable product, and unless proper care is taken over half its value may be lost. The losses occur through: (1) Loss of urine; (2) loss by leaching; and (3) loss of nitrogen by fermentation.

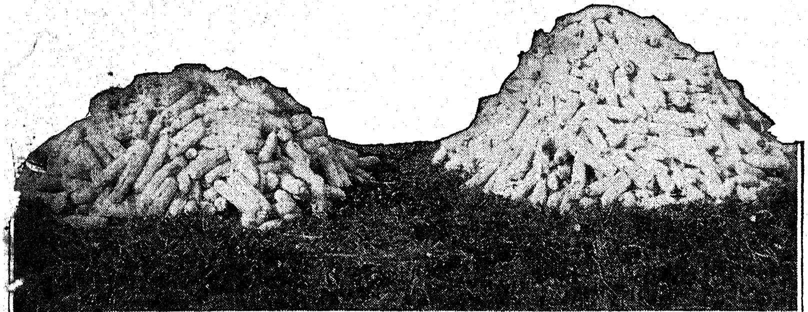
A manure pile against the side of the barn and under the eaves, or manure lying for months in an open barn yard, is a sight all too common. When manure is thus exposed to the leaching action of rains, the losses are great, even amounting to half of the total value in periods of 2 to 5 months. Unfortunately, the loss falls on the constituents which are most soluble and therefore most quickly available to plants.

When manure is stored, the mass must be well packed and kept damp, or hot fermentation will occur, in which a large part of the nitrogen may be lost. In this process there is a rapid formation of ammonia from the nitrogenous compounds, and much of this ammonia escapes as gas into the air. The strong smell which is very noticeable in unventilated horse stables is due to this escaping ammonia gas, produced by the breakdown of nitrogenous compounds in the urine. In still other changes which may take place, free nitrogen gas may be formed, which is likewise lost into the air.

When the pile of manure is well packed and is kept damp, these changes cannot go on, but only the decay which makes the plant food more available and produces what is termed "well-rotted manure." If the manure is very loose and dry, "fire fanging" may occur, the manure becoming grayish or dusty in appearance. This change, which is brought about by certain molds, causes serious losses of nitrogen. Phosphorus and potassium are not lost through fermentation, but heavy losses of these minerals may occur through leaching.

To reduce the losses of fertility in manure to the minimum, first of all, the urine should be saved by having tight gutters and using plenty of bedding. When possible, the manure should be drawn directly to the fields and spread each day. This is not advisable, however, in winter on very sloping land when covered by deep snow, as much fertility may wash down the hill in the spring. Even when the fresh manure is spread daily on the fields, a heavy loss of nitrogen may occur if it is not soon plowed under or disked under.

Adding superphosphate (acid phosphate) to the manure greatly decreases the losses of nitrogen, no matter whether it is spread at once or whether it is properly stored. Also, since manure is much richer in nitrogen than in phosphorus, the phosphorus fertilizer usually increases crop yields considerably. Caustic forms of lime, such as hydrated lime, increase the loss of nitrogen in the form of ammonia from manure that has fermented, but may be used daily in the gutter without detrimental effect.



THE RESULT OF ALLOWING MANURE TO WASTE AWAY

When manure is allowed to waste away as in the illustration on Page 570, not only is much of the weight of the manure lost, but that which remains contains much less fertility per ton than fresh manure. The pile of corn at the left was grown on a plot fertilized with manure which had been exposed to the weather over winter. The large pile at the right was grown on a plot fertilized with the same amount of fresh manure. (From Wisconsin Station.)

When manure cannot be spread at once on the land, it should be stored under cover, if possible, and in well-packed piles which are kept moist to prevent hot fermentation. The shed or pit should preferably have a concrete floor, to prevent any draining away of liquid. It is an excellent plan to mix the manure from horses, sheep, or poultry (which is drier), with the cattle or pig manure (which contains more water).

The value of manure is well preserved when a deep layer is allowed to accumulate in a well-bedded stable in which stock run loose. The layers of manure under the surface are thoroughly packed by the animals and are kept damp, so the loss of nitrogen is reduced to a minimum.

When it is necessary to leave manure outdoors, the pile should be built with the sides perpendicular and the top should be flat or sloping slightly toward the center, so that all rain will soak into the pile instead of draining off as from a stack of hay. It is impossible to prevent all waste when manure is stored, but under proper management not over 25 to 30 per cent of the nitrogen and practically none of the phosphorus and potassium will be lost.

In some European dairy districts large concrete tanks are used for holding the urine and solid feces, not including bedding. Here the contents can be stored without appreciable loss of nitrogen. The mixed contents are pumped into tanks, somewhat like a street sprinkler, and distributed on pasture fields grazed rotationally, after the stock have finished grazing a plot. This method is used to some extent in certain areas of this country, especially in the Pacific Northwest. It is very efficient in conserving fertility, but requires additional labor.[19]

QUESTIONS

1. How are the fertilizing values of feeding stuffs and of farm manures computed?
2. What beneficial effects does farm manure produce in the soil in addition to the plant food it supplies?
3. About what percentage of the fertilizing constituents in their feeds do mature work horses (not pregnant or nursing foals) void in the manure; young calves; dairy cows?
4. Give examples of feeds which are high and of others which are low in fertility value.
5. How is the manurial value of a feed computed?
6. A farmer who intends to fatten feeder steers has on his farm shelled corn, corn silage, and clover hay. To provide a well-balanced ration, he sells 10 tons of corn and buys as much cottonseed meal as he can with the proceeds. Using local market prices and assuming that the feeding value of the cottonseed meal is enough greater than that of the corn to pay for hauling, find the gain or loss in manurial value from the exchange.
7. Compare the fertility lost in selling a ton of corn; a ton of fat pigs; a ton of butter.
8. What are the average amounts of fertilizing constituents in a ton of mixed fresh farm manure?
9. Discuss the differences in composition and value of manure from horses, dairy cows, fattening cattle, sheep, swine, and poultry.
10. What are "hot manures" and "cold manures"?
11. About how much manure, including bedding, is produced per head annually by horses; by dairy cows; by sheep; by hogs?
12. Why is it important that the urine be saved?
13. What kinds of bedding are used for stock in your district?
14. Discuss the losses that occur in farm manure and tell how it should be handled to reduce the losses to a minimum.

REFERENCES

1. Grindley, Mumford, Emmett, and Bull, Ill. Bul. 209.
2. Bear, King, and Bender, N.J. Bul. 730.
3. Ames and Gaither, Ohio Bul. 246; Papanos and Brown, Conn. (Storrs) Bul. 272; Jacobson and Swanson, Conn. (New Haven) Special Bul., 1950; Rahn, Del. Bul. 281; Donaldson, Mass. Exten. Leaflet 57; Yushok and Bear, N.J. Bul. 707; Bear, King and Bender, N.J. Bul. 730; White, Holben, and Richer, Penn. Bul. 469; Van Slyke, Fertilizers and Crop Production; Thorne, Farm Manures.
4. Salter and Schollenberger, Ohio Bul. 605; see also: Linsley and Crane, Ill. Cir. 595.
5. Ames and Gaither, Ohio Bul. 246.
6. Ross, Ill. Bul. 240.

7. Frane, Ill., mimeo. rpt.
8. Fushok and Bear, N.J. Bul. 707; Ames and Gaither, Ohio Bul. 246; Forbes et al., Ohio Buls. 295, 308, 330, 365.
9. Salter and Schollenberger, Ohio Bul. 605; White, Holben, and Richer, Penn. Bul. 469; Olson, S.D., Jour. Dairy Sci., 23, 1940, pp. 355–360.
10. Doane, Md. Bul. 104; Savage and Albrectsen, N.Y. (Cornell) Rpt. 1931.
11. Snapp, Beef Cattle, 4th Ed., p. 36.
12. Crowl, Ind., Hoard's Dairyman, Oct. 25, 1953.
13. Odland and Knoblauch, R.I. Bul. 251; Midgeley and Varney, Vt. Rpt. 1945.
14. Brundage, Ind. Cir. 395; Crowe, Ind., Hoard's Dairyman, Oct. 25, 1953; Trimberger, N.Y., information to the author.
15. Woodard, Shepherd, and Graves, U.S.D.A., Misc. Pub. 179.
16. Vt. Bul. 360.
17. Bartlett, N.J. Sta., information to the author.
18. Bartlett, N.J. Rpt. 1925.
19. Schulz, Hoard's Dairyman, May 25, 1950; June 10, 1950; West Va. Bul. 349, Part 1.

PART III

FEEDING FARM ANIMALS

CHAPTER XXV

GENERAL PROBLEMS IN DAIRY HUSBANDRY

I. Factors Determining the Efficiency of Dairy Cows

996. Economy of food production by dairy cows.—It is highly important for the health and well-being of humans that they have an abundant supply of milk and other dairy products. This is because the great nutritive merits of milk put it in a class by itself as a human food. (**269**) Fortunately, dairy cows not only excel in the nutritive value of the food they produce for us, but they also excel in the economy with which they produce this unrivalled food.

It has been shown in Chapter XII that dairy cows even surpass swine, our most efficient meat producers, in the efficiency with which they convert the digestible nutrients in the feed they eat into energy in food for human beings. (**351–352**)

The chief nutritive merit of milk is not, however, the energy it furnishes, but the rich store of the nutrients that we need to make good the deficiencies in our cereal foods. We need milk's abundant supply of highest quality protein, its high vitamin A value, its content of other vitamins, its richness in calcium, and the especial value of the milk sugar in our diet. (**353**) Considering all these factors, the dairy cow may well be called "the foster mother of the human race," a title which was apparently first bestowed on her by W. D. Hoard of Wisconsin.

When we compare the economy of milk production by the dairy cow with meat production by beef cattle, sheep, or poultry, the efficiency of the cow is striking. For example, good dairy cows yield in their milk, per acre of crops eaten, over 5 times as much energy and nearly 4 times as much protein as is contained in the beef made by steers from the same amount of feed.[1]

997. High producers are economical producers.—One of the most important facts in dairying is that high-producing cows are almost always much more economical producers of milk and butterfat than are low producers. Also, the return over feed costs is much greater for high producers. These facts are well shown by the table on the next page. In this table data for cows completing records of production in dairy-herd-improvement associations during 1952, in this country, are grouped according to the level of production.[2]

For the dairyman, the most important fact shown by the table is that the return over feed cost steadily became greater as the yield of milk and fat increased. This was true even at extremely high levels of production. Also, the feed cost of producing 100 lbs. of milk was much less for high producers than for the low yielders.

While this fact is always extremely important, it is vital when the price received for milk is low in comparison with the cost of feed and labor. At such a time only the dairyman with high-producing cows stands any chance of securing a reasonable return over feed cost.

The table shows that as the production became greater, there was a steady increase in the cost of feed, but

the value of the product increased much more rapidly. For example, the cost of feed for the group averaging 13,953 lbs. milk and 501 lbs. fat was $69 more than for the second group, which averaged only 5,048 lbs. milk and 241 lbs. fat, but the value of the product was $345 greater. This made the return over feed cost nearly three times as great for the cows in the higher-producing group.

Relation of level of production to cost of feed and return above feed cost *

Milk production, range	Average yield of milk	Average yield of fat	Value of product	Cost of roughage including pasture	Cost of concentrates	Total cost of feed	Return above feed cost	Feed cost of 100 lbs. milk
Lbs.	Lbs.	Lbs.	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
3,500–4,499	4,076	196	247	67	69	136	111	3.34
4,500–5,499	5,048	241	297	70	76	146	151	2.89
[illegible]500–6,499	6,029	281	348	74	85	159	189	2.64
[illegible],499	7,010	316	393	76	90	166	227	2.37
[illegible]8,499	7,994	345	431	79	95	174	257	2.18
8,500–9,[illegible]99	8,984	367	465	82	100	182	283	2.03
9,500–10,499	9,985	391	496	84	105	189	307	1.89
10,500–11,499	10,984	413	528	86	108	194	334	1.77
[illegible]–12,499	11,970	440	565	87	113	200	365	1.67
[illegible]–13,499	12,957	469	599	88	118	206	393	1.59
13,500–14,499	13,953	501	642	90	125	215	427	1.54
14,500–15,499	14,950	533	682	91	130	221	461	1.48
15,500–16,499	15,936	565	722	91	134	225	497	1.41
16,500–17,499	16,922	599	746	88	138	226	520	1.34
17,500–18,499	17,944	638	809	90	154	244	565	1.36
18,500–19,499	18,941	673	837	96	156	252	585	1.33

* Based on the records of 50,005 DHIA cows, selected at random, that completed a full 12-month testing period in 1952. Cows producing less than 3,500 lbs. of milk and those yielding 19,500 lbs. and over are omitted in this table, because of the small numbers in these groups.

Fully as important is the fact that the feed cost per 100 lbs. milk was only $1.54 for the cows yielding 501 lbs. fat, while it was $2.89 for the group averaging 241 lbs. fat.

This table effectively disproves the statement, sometimes made, that greater net returns are secured from moderate rates of production than from the high levels of production reached by excellent cows fed in accordance with their nutrient requirements.

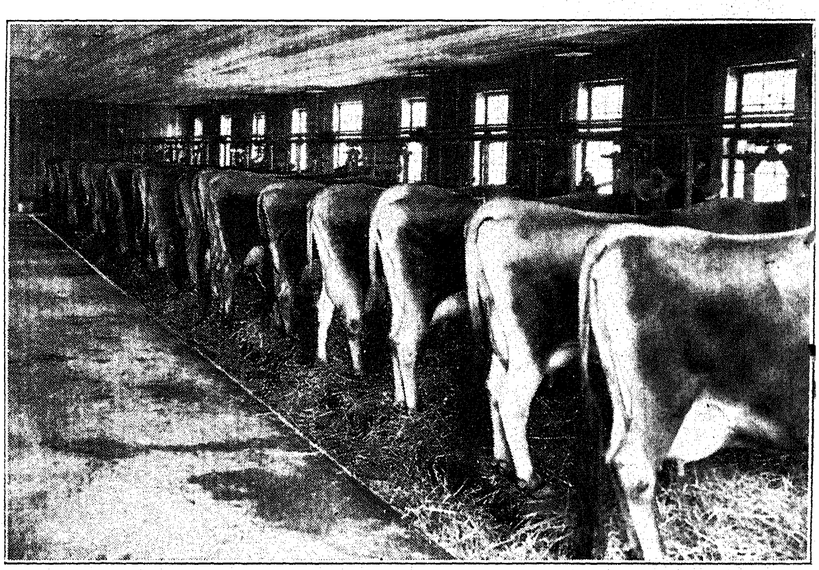
998. Why high producers are more efficient.—High producing cows are more efficient than low producers chiefly because of their great inherited capacity for milk production, combined with a strong constitution and the ability to consume and utilize a great amount of feed. They secrete a large yield of milk and, because of the great quantities of nutrients they put into their milk, they have keen appetites. If fed properly, they eat much more feed than low producers, and use this feed more efficiently for milk production. This is because they have left for milk production a much larger proportion of the feed nutrients, after their maintenance requirements are met. (**1001**)

Missouri experiments showed that high producers and low producers do not differ appreciably in the efficiency with which they digest their feed.[3] Opinions differ as to whether or not high producers require less feed than low producers merely to maintain their bodies. In the Missouri studies there was no difference in this respect between high and low producers. On the other hand, from statistical studies of the results of feeding experiments, Headley of the Nevada Station concluded that high producers required somewhat less nutrients than did

low producers for mere maintenance.[4] One factor causing the difference between high producers and low producers may be the size or rate of activity of the thyroid gland, which regulates the rate of metabolism in the body.[5] (54) Cows in warmer climates seem to have smaller thyroids than in our northern states.

While the chief difference in efficiency of milk production is between high producers and low producers, there may be some difference in efficiency between cows that yield the same amounts of milk and fat. For example, let us take two cows which both produce in a year 10,000 lbs. of milk containing 3.7 per cent fat, but one cow weighs 1,000 lbs., while the other weighs 1,400 lbs.

The larger cow will generally consume considerably more feed than the smaller cow, because she needs more nutrients to maintain her larger body. If she produces no more milk than the smaller cow, her efficiency will obviously be lower. To compare the real efficiency of various cows, we must therefore consider not only milk and fat yields but also live weight.



HIGH MILK PRODUCTION NECESSARY FOR EFFICIENCY

High-producing cows are almost always much more economical producers than are low producers. A high-producing herd of Jerseys.

999. Fat-corrected milk yields.—Milk containing the various percentages of fat differs widely in energy content per pound. Therefore to compare the actual amounts of milk energy produced by various cows, the yields must be equated, or changed, to a uniform energy basis. This is done by converting the various actual yields to equivalent amounts of milk of a uniform fat percentage, and therefore of the same energy content.

The usual method is to convert the yields, by the formula developed by Gaines of the Illinois Station, to amounts of "4 per cent fat-corrected milk" (commonly called merely "fat-corrected milk," and abbreviated to F.C.M.).[6] This is done by multiplying the actual milk yield by 0.4 and then adding to this product the actual fat yield multiplied by 15. In condensed form, the formula is:

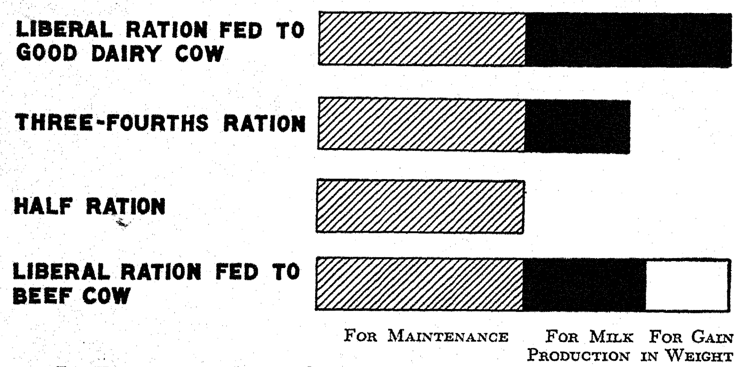
$$\text{F. C. M. (4 per cent fat-corrected milk)} = 0.4 \times \text{milk} + 15 \times \text{fat}.$$

If desired, the milk yields can be converted to some other uniform fat percentage than 4 per cent, by the use of a different formula.

To compare the production of heifers with that of mature cows, the actual yield is converted to a "mature equivalent basis" by multiplying the yield by an "age-correction factor." (1055)

1000. Measuring the efficiency of milk production.—The efficiency with which various cows produce milk can be compared by computing the energy content of the milk each has produced in a year and dividing this by the energy in the total digestible nutrients in the feed each has consumed. The quotient is called the *gross efficiency of milk production.*[7]

USE OF FEED BY COWS



IT PAYS, TO FEED GOOD DAIRY COWS LIBERALLY

When fed liberally a good dairy cow can use half her feed for milk production. When fed a three-fourths ration she can use only one-third of her feed for producing milk, and when fed a half-ration she needs all her feed to maintain her body. A beef cow, if fed a liberal ration, will turn part of her surplus feed into fat instead of milk.

Each pound of 4 per cent fat-corrected milk has approximately 340 Calories of energy, and each pound of total digestible nutrients supplies about 1,814 Calories. The formula for computing the gross efficiency of milk production is therefore:

$$\text{Gross efficiency} = \frac{340 \text{ Cal.} \times \text{lbs. of F.C.M.}}{1814 \text{ Cal.} \times \text{lbs. of T.D.N.}}$$

In computing the amount of total digestible nutrients consumed in a year, the amount the cow secures from pasturage must be estimated as closely as possible, since it may furnish the major part of the nutrients during the growing season.

Brody of the Missouri Station has compiled the records of production and feed consumption of 243 cows at various experiment stations.[7] These cows averaged 1,087 lbs. in weight and produced an average of 10,315 lbs. of 4 per cent fat-corrected milk a year. Their average gross efficiency of milk production was 30.1 per cent.

Various cows of the same live weight and productive capacity may differ somewhat in the efficiency with which they digest and utilize feed, but these differences are not generally large, if the cows are healthy. Brody has therefore prepared a detailed table which shows the estimated gross efficiency of cows of various live weights and producing various amounts of 4 per cent fat-corrected milk a year.

According to this table, the gross efficiency for 1,000-lb. cows yielding 5,000 lbs. of fat-corrected milk a year (about our United States average) is 20.8 per cent. At double this yield, 10,000 lbs., the gross efficiency rises to 30.9 per cent. According to this table, a 1,000-lb. cow producing 25,000 lbs. of 4 per cent fat-corrected milk a year would have a gross efficiency of 44.0 per cent.

1001. Feed good cows liberally, but not poor cows.—Unless cows of high productive capacity are fed with suffi-

cient liberality to provide them with the nutrients they need for the production of a large amount of milk and fat, their yield will soon decline to the level permitted by the nutrients they receive. Many cows which could be profitable producers are thus forced into the inefficient and unprofitable class, because their owners do not appreciate this important fact.

A well-fed dairy cow yielding about 1 lb. of butterfat a day requires nearly one-half of the feed she eats for maintaining her body. She therefore has left to use for milk production only about one-half of her feed. If she is fed only two-thirds as much, she will digest the scanty ration a trifle better, but she will still need nearly as much feed as before to maintain her body. As a result of the scanty feeding, she will probably have available for milk production only 30 per cent or less of the total feed she eats. This great reduction in the amount of feed that is left for milk production will much more than offset the slightly greater digestibility of a scanty ration. (101) Also, the overhead expenses per 100 lbs. of milk are greater when a cow is producing at a low rate.

It is just as unwise to overfeed a poor cow as it is to be stingy with a good producer. If a cow lacking productive ability is fed liberally, she cannot increase her milk production beyond her inherited capacity. All she can do is to store the excess nutrients in the form of body fat, instead of turning them into milk. The best plan is to get rid of such a cow, for she will not pay for her keep. If she is kept, it is important that she be fed according to her actual production, instead of being given as much grain as the good cows in the herd.

1002. Building a profitable herd.— The farmer who has a herd of low-producing, unprofitable cows cannot hope for any real success in dairying until he has secured a herd of good producers. He should therefore at once take steps to accomplish this result. Even if he starts with scrub or with beef-type cows, he can in 5 to 6 years make considerable improvement in his herd, if the calves are sired by a purebred, bred-for-production bull.

However, it is usually best to make more rapid progress by selling the poorest producers in the herd and replacing them with a few high-producing grade or pure-bred cows of the breed desired. If a good purebred dairy bull is then always used in the herd, and the lowest yielders are culled out each year, in a relatively short time he should have a herd of efficient producers.

The striking improvement which is made in one to three generations by using good purebred dairy bulls on scrub cows or on beef-type cows is shown in experiments by the Iowa, Minnesota, Oklahoma, and South Dakota Stations and the Canadian Department of Agriculture.[8]

In the Iowa experiment, for example, the original scrub cows, with good feed and care at the Station produced only 4,110 lbs. of milk and 192 lbs. of fat a year. Their daughters, sired by purebred bulls, produced 41 per cent more milk and their grand-daughters, carrying three-fourths of dairy blood, nearly twice as much as the original scrubs. The grades not only yielded more milk a day, but also were much more persistent milkers than the scrubs, whose lactation periods were short.

Even more important than the greater yield of milk, is the fact that the cost of feed for 100 lbs. milk was 13 per cent less for the three-quarter bloods, even though they were only heifers, than for their scrub grand-dams. Not only was the production rapidly improved by grading up, but also just as striking improvements were made in the conformation of the animals, especially in their udders. The grades, especially of the second cross, were stamped plainly with the breed characteristics of the purebred sires.

Scrub heifers, raised at the Station out of the scrub cows and the scrub bull, produced 10 per cent more milk and 13 per cent more fat a year than their scrub dams. This small increase, which was strikingly inferior to that from the use of purebred sires, was due to the fact

that the heifers were so fed and cared for as to develop fully what little capacity they did have for milk production.

In these trials the offspring from one of the purebred sires used on the scrub cows fell much below the others in productivity. This illustrates the well-known fact that to build up a herd a sire must be able to transmit high production, and not be merely a purebred.

By joining an artificial breeding association a dairyman in most of our dairy districts can now have his cows bred at moderate cost to an outstanding sire, even if he has only a few animals. He can thus gain the great advantage from the use of bulls which would be too valuable and high-priced for him to own alone.

1003. Type and production; purebreds vs. grades.—Good-producing dairy cows are usually of the dairy type, and poor producers show less of the dairy conformation and characteristics. However, even experts are often unable to tell by appearance alone whether a cow will be a profitable producer. Studies have shown that in purebred or high-grade dairy cows the correlation between type score and milk production is rather low.[9] The only reliable way of determining the productive capacity of a cow is from a record of the actual amount of milk and fat she yields.

In studies of the conformation of 1,000 purebred dairy cows and their production records, Swett of the United States Department of Agriculture found that length of head was the body measurement most consistently correlated with milk production.[10] Body depth, which indicates the size of the internal organs, was also definitely correlated with production.

Practically all dairymen now recognize that cows distinctly of beef type are not economical producers of milk. The dairy type and the beef type are the result of breeding for many generations with opposite objectives. The beef animal has been developed to store in its carcass the largest possible amount of meat. On the other hand, the dairy cow has been bred for the primary object of producing large yields of milk and butterfat. As a result, though a good dairy cow will put on flesh when she is dry, the impulse to milk production is so strong when she is in milk that even under liberal feeding she shows little or no tendency to fatten. Instead, she uses all the surplus feed above maintenance for the manufacture of milk.

Dairy-herd-improvement association records show that, on the average, purebred dairy cows produce more milk and fat and return a greater income over feed cost than do grade cows. This is because they have a greater inherited capacity for milk production. For example, in one study 63,739 registered purebred dairy cows in dairy-herd-improvement associations produced a yearly average of 8,443 lbs. of milk and 325 lbs. of fat, while 107,309 grade cows averaged 7,623 lbs. of milk and 298 lbs. of fat.[11] Still more important was the fact that the yearly net return over feed cost was $20 per head more for the purebreds.

It is possible by the use of excellent purebred sires in a grade herd for many years, combined with careful culling, to develop a herd that probably cannot be distinguished in appearance or production from a herd of purebreds. However, it must be borne in mind that the merits of high grades are due to their purebred ancestors, and not to the trace of scrub blood they still possess.

1004. Size of cow.—If equally well bred, the larger cows of a breed tend to produce more milk than the smaller ones. This is but natural, for a large cow has a greater capacity to consume and utilize feed. However, the amount of milk a cow will produce depends much more on her inherited dairy ability than upon her size. In developing a high-producing herd, one should therefore base his selection primarily on productive capacity rather than giving undue attention to size. If a large cow and a cow of moderate size produce equal amounts of milk, the cow of moderate size will be more profitable. This is because she will require somewhat less feed to maintain her body than the large cow.

In New York studies just completed,

the weights of the cows in 3,568 dairy-herd-improvement association herds of the various breeds were estimated by tape measurements, and the records of production and of feed consumed were grouped by weight classes in each breed.[12] Combining the results for all the breeds, an increase of each 100 lbs. in estimated live weight resulted in an average increase of 661 lbs. of 4 per cent fat-corrected milk. Not only was the milk production higher for the larger cows in each breed, but also the return over feed cost was decidedly greater. Similar results were secured in an earlier New York cost accounting study.[13]

There is an even greater difference in the net return per cow over all costs, including labor, for the larger cows in the breed. This is because the expenses other than feed costs are not much greater for large cows than for smaller ones.

One must, however, use good judgment and not develop a herd of cows that are too large in size for the particular conditions. For example, the stalls in the stable may be too small for very large cows, or the pasture fields may be so rough that they are better adapted to more agile cows of moderate size.

While the larger cows of a breed tend to excel on a per head basis, the smaller cows often surpass them in the efficiency with which they produce energy in milk from the total digestible nutrients in their feed.[14] This is because most dairymen tend to judge their cows by the amount of milk each cow produces, without paying enough attention to their relative sizes. Unless the smaller cow produces almost as much milk as the large one, she is often culled out because of low production.

The most accurate method of comparing the real merit of various cows is to compare them on the basis of their efficiency in converting total digestible nutrients in their feed into milk. Unfortunately, this is nowhere near as simple as to compare them on the basis of annual yield of milk and fat.

Certain investigators have believed that in cows equally well bred the milk yield tends to be directly proportional to the live weight.[15] On the other hand, others conclude that the milk yield is more nearly proportional to the 0.70 or 0.75 power of the live weight.[16]

1005. Weed out low-producing, unprofitable cows.—Although the average production of the dairy cows in the United States has been increased considerably as better feeding and breeding practices have been adopted by dairymen, the production is still only about 5,630 lbs. of milk and 225 lbs. of f[illegible]e cow. Even with average prices for [illegible] products, probably one-fourth or more of the dairy cows fail to pay for their feed and care. When dairy prices are low, the condition is even more serious.

The chief reason why such a condition is found now, when the principles of successful selection, feeding, and care of dairy cattle have long been known, is that the owners do not know which of their cows fail to yield enough milk to pay for their feed and care. They do not realize that though the gross income from their herd would be reduced [illegible] weeding out the "boarders," their profits would be decidedly increased.

It is therefore extremely important for a dairyman to secure the record of production of each cow in his herd. Fortunately, such records may be easily secured by the use of the milk scales and the Babcock fat test. Knowing the production of each cow and the approximate amount of feed she has consumed in a given period, the dairyman can discard the unprofitable animals, and gradually build up a herd of high producers at small expense by using a bred-for-production sire and saving the heifer calves from the best cows.

By this means the average yield of fat for the herd can be gradually increased year by year, until it is raised to 300 lbs., later to 350 lbs., and then even higher. As good cows sometimes have "off years" in production, animals should not be discarded after a single year's trial, if there is good reason to believe they will do better in the future.

1006. Keeping records of production.—For most farmers who have the

services available, belonging to a dairy-herd-improvement association (commonly abbreviated to DHIA) or to an owner-sampler club is the most convenient method of securing records of production on each of their cows. These services are relatively inexpensive, and the advice furnished concerning the feeding and management of the herd is of much value.

In dairy-herd-improvement associations in the United States a supervisor is employed who spends one day every month with each of the herds in the association. (In certain associations the tests are made bi-monthly, instead of each month.) Arriving on the farm in the afternoon, he weighs and samples the milk from each cow at milking time and also weighs the feed. The following morning this is repeated, after which the samples of milk from each cow are mixed thoroughly and tested for butterfat. From this day's record he computes the milk and fat production and the cost of feed for each cow for the current month. The data for each cow are recorded in the herd-record book, so that the dairyman has available the record of each cow for every month of the year. The tester also studies the local feed market and aids the dairyman in working out economical rations. In certain states, central testing laboratories have been set up, and the testing of the samples and the computation of the records is done there.

The production records of each cow for the first 305 days of each lactation are sent by the tester to the state agricultural college, from which they are transmitted to the Dairy Research Branch of the United States Department of Agriculture. These records are used in proving the transmitting ability of the sires used in the various herds and in making herd analyses, which are studies of the breeding worth of the various cow families.

The value of dairy-herd-improvement association records in increasing the efficiency of dairying is shown by the fact that in 1955 the average production of the cows in the associations in this country was 9,363 lbs. of milk and 372 lbs. of fat. For the same year the average yield of all cows milked in the United States was about 5,630 lbs. of milk.

In the owner-sampler type of cow testing, the dairyman weighs and samples carefully the milk from each cow for one day each month and then mails the samples and the record of weights to a central testing laboratory, usually conducted by the state college of agriculture. Here the samples are tested, the amount of fat is computed, and the records mailed back to the dairyman. This plan is especially convenient for farmers who have only a few cows or who live in localities where no dairy-herd-improvement association is available.

If a dairyman does not have available the services of a dairy-herd-improvement association or a dairy-record club, he can himself keep a record of each cow's production. The best way is to weigh and record each milking from every cow. This does not require much work, if a convenient spring balance is used and handy milk sheets for entry of the records. Such daily individual records make possible the feeding of each cow with the greatest economy, enable the herdsman to detect sickness quickly by the decline in milk flow, and aid in judging the efficiency of different milkers. Where the weight of each milking is recorded, it is sufficient to take samples for fat testing once a month for one or preferably two consecutive days. Those who feel that they cannot spend the time necessary to weigh each milking can obtain reasonably accurate records by weighing and sampling the milk regularly for one day each month.

1007. Official testing of dairy cows.—In this country two different types of official testing of dairy cows are provided by the dairy breed registry associations, the testing being done by supervisors, or testers, under the direction of the state agricultural college. In the *advanced registry* a breeder may enter one or more selected cows at any time for production records of either or both 305 or 365 days in length. Daily milk weights must be

kept by the dairyman. The test periods are preceded by a preliminary dry-milking, each cow being milked dry under the supervision of the tester.

In the *herd improvement registry* all the cows in the herd must be tested, with the possible exception of certain cows which have previous official records. A one-day test, without preliminary dry-milking, is conducted each month throughout the year, and the keeping of daily milk weights is not required.

The official production records are published by the breed associations. A high record increases the money value, not only of the individual cow, but also of her relatives, for progressive breeders in buying animals now rely more and more on production records instead of merely show-ring successes.

Recently, certain of our dairy breed associations have adopted plans and regulations under which the production records of the individual cows in a DHIA herd are accepted for publication and for the proving of sires, in the same manner as are the advanced registry records.

While a test covering one lactation period is a good index to the maximum productive capacity of a cow, a still better measure of her worth is a record over several consecutive years. Likewise, the best index to the value of the blood lines represented in a herd is provided by the records of all the cows in the herd, year after year. This is far more reliable than official tests on a few selected cows which are pushed to the very utmost when they are on test. For these reasons, the herd-test plan is becoming increasingly popular with breeders.

All dairymen recognize that successful reproduction within a normal period is fully as important as a record of high milk yield. To an ever increasing extent experienced breeders now favor, instead of a 365-day test, the 305-day test with the additional requirement that the cow calve within a definite period.

The feeding and care of cows for high records of production are discussed in Chapter XXVI.

II. Nutrient Requirements of Dairy Cows

1008. Requirements for milk production.—It has already been shown in Chapter X that the nutrient requirements of animals producing a large amount of milk differ greatly from the requirements of those being fattened or of those [illegible] muscular work.

For efficient milk production it is essential that dairy cows receive: (1) A liberal amount of total digestible nutrients or net energy; (2) a relatively large amount of protein, supplied by suitable dairy feeds; (3) at least a certain minimum amount of fat; (4) sufficient phosphorus, calcium, common salt, and other essential mineral nutrients; (5) an ample supply of vitamins A and D and of certain unknown factors or vitamins that may not be furnished by very re[illegible] rations; and (6) a ration that is palatable to the cows.

The amounts of nutrients required by any particular milk cow will depend, first of all, on her size, since maintenance requirements depend upon body size. Her needs will also depend on the amount of milk she is producing, and on its richness in fat. If she is a heifer, she will require additional nutrients for the growth of her body. When she is pregnant, there will be a still further need of nutrients for the development of the fetus. This latter requirement will be insignificant in amount during the first part of pregnancy, and will not be large even during the latter part. The nutrient requirements of dairy calves, dairy heifers, and dairy bulls are discussed in Chapter XXVII.

The Morrison feeding standards for dairy cattle are given in Appendix Table III. The standards for dairy cows give first the amounts of nutrients required for the maintenance of cows of various live weights, and second, the amounts of nutrients required for the production of 1 lb. of milk containing various percentages of fat. Also, the additional amounts of nutrients are given which are advised for cows during the last few weeks of pregnancy. For the reasons

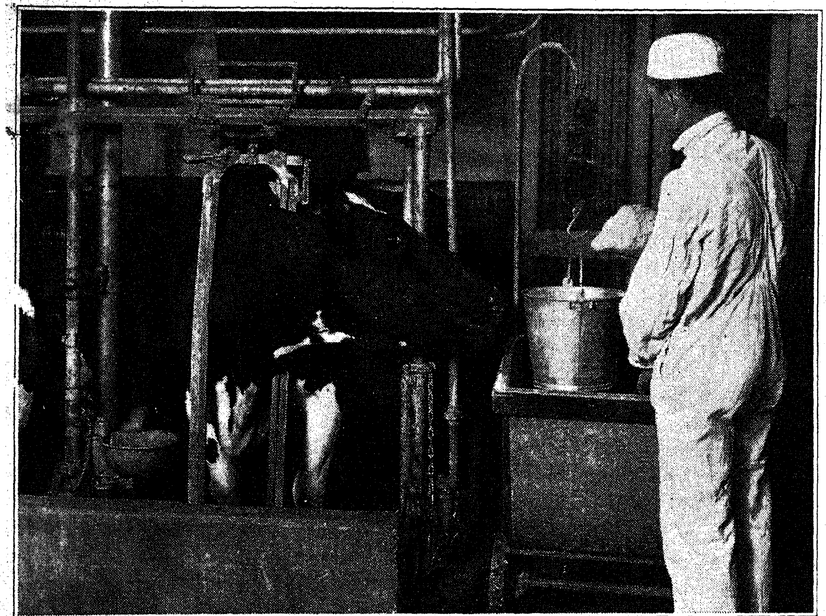
previously, a range is given in amounts of digestible protein and of digestible nutrients recommended the standards. (317, 325.)

Under usual conditions sufficient nu-nts should be supplied to meet the per figures in the range stated in the ndards. When protein-rich feeds are expensive, it may be most economi- feed no more protein than is required to meet the lower recommendations. Likewise, when grain and other concentrates are very expensive in comparison with hay and other roughages, it may be most profitable to supply only as much total digestible nutrients or net energy as recommended in the lower recommendations in the standards.

1009. Guides in selecting well-balanced rations.—Any intelligent dairyman can compute an economical, well-balanced ration for his cows by following the methods explained in Chapters XI and XII and familiarizing himself with the nutrient requirements for milk production which are discussed on the following pages. However, the computing of a balanced ration takes considerable time and trouble if one is not experienced in the process.

To simplify the selection of efficient rations for milk production, convenient feeding guides are given in Appendix Tables VII and VIII. By the use of these guides the balancing of rations is reduced to a simple recipe basis. Though these feeding guides are very simple, they have been worked out carefully on a scientific basis, so that they are reliable guides in practical feeding.

First, there are given in Appendix Table VII formulas for many different concentrate or grain mixtures which will make balanced rations when fed with the roughages indicated. One can readily determine which of the several mixtures in the proper group will be cheapest under the local conditions. If desired,



LIBERAL CONCENTRATE FEEDING NECESSARY FOR HIGH YIELD

Maximum milk production cannot be secured unless cows are fed a liberal amount of concentrates in addition to good roughage. Local conditions will determine what level of concentrate feeding will be most profitable. (From Wisconsin Station.)

changes can be made in these formulas by following the directions given in the paragraphs which immediately precede the formulas.

1010. Determining how much concentrates each cow needs.—After selecting an economical concentrate mixture that will make a balanced ration with the roughage to be fed, it is next necessary to know how much of the concentrate mixture each cow in the herd should receive. Various "thumb rules" are often used for estimating this. A more convenient and also more accurate method is to use the "Grain Feeding Tables" given in Appendix Table VIII.

The first of these tables is for use when the cows are not on pasture. It states the number of pounds of a good concentrate mixture, or so-called "grain mixture," required by cows producing various amounts of milk of different fat percentages, when various amounts of roughage are eaten. The second table similarly shows the amounts of concentrates needed by cows on different grades of pasture. Before using these tables, one should read carefully the directions that immediately precede them.

Sufficient amounts of grain mixture are advised in these tables to meet the recommendations of the feeding standards and to maintain good yields of milk under usual conditions. When concentrates are very expensive in comparison with roughages, it may then be most economical to feed a smaller amount of grain mixture than stated in the tables.

It is recommended in the paragraphs that precede the tables that excellent cows which have run down in flesh should be fed somewhat more grain mixture during the latter part of the lactation period than is stated in the tables. Also, heifers need a trifle more grain mixture than shown in the tables, because they are still growing.

It is well worth while for a dairyman to understand thoroughly the method of computing economical rations which are balanced in accordance with the feeding standards. He will then know how to make balanced rations under any special conditions that may arise. However, from the standpoint of his returns, the most important point is to be sure to feed balanced rations, though he has not taken time to work them out himself. In any case, if in doubt as to the best ration to use, a dairyman will find his county agent or his agricultural college and experiment station ready to advise him.

In computing rations for dairy cows, it is necessary to know their approximate weights. If one does not have suitable scales available for weighing the individual cows, their weights can be estimated from a measurement of the heart girth. Appendix Table IX shows the approximate weights of dairy cows having different heart girths.

1011. "Thumb rules" not accurate guides.—Various "thumb rules" have been widely used for estimating the amount of grain mixture required by cows producing different amounts of milk and fat. However, none of these thumb rules is so convenient or so accurate as the grain feeding tables.

For example, a common thumb rule is: Feed 1 lb. of grain mixture per day for each $2\frac{1}{2}$ to 4 lbs. of milk, depending on the richness of the milk and the quality of the roughage fed. Under most conditions this and similar thumb rules underfeed the high producers and overfeed the poor cows. This is because these rules do not take into consideration the important fact that when a cow is fed a liberal amount of good roughage, she receives a greater amount of nutrients than she needs for mere body maintenance. Her concentrate allowance should accordingly be based, not on the total amount of milk she yields, but on the amount she is producing beyond the amount which she can make from the roughage.

Certain "thumb rules" have been devised which take these facts into consideration. For example, one such rule, for use when good roughage is fed in the usual amounts, is: For Holsteins, feed 0.4 lb. of concentrates for each pound of milk above a yield of 16 lbs.[17] Similar rules are stated for cows of other breeds.

While these rules are more accurate than the older "thumb rules," they are less convenient than the grain feeding tables in Appendix Table VIII. Also, they are based merely on the usual amounts of good roughage, and cannot be used when a very liberal amount of excellent roughage is fed, or when, on the other hand, only a scanty allowance of roughage is used. The grain feeding tables give definite recommendations to fit these varied conditions.

1012. Feeding standards vs. actual requirements.—In the following discussions concerning the nutrient requirements of dairy cows and concerning the recommendations made in various feeding standards, the purpose and nature of feeding standards must be borne clearly in mind. Feeding standards are intended as practical, convenient guides for the proper feeding of the various classes of stock. They are not statements of the theoretical minimum requirements of nutrients.

It has been shown previously that when animals are fed a liberal ration, they digest a slightly smaller percentage of the food nutrients than when they receive a scanty ration. (**101**) Practically all the experiments to determine the digestibility of various feeds have been conducted, not with liberally-fed dairy cows, but with steers or wethers fed rather limited rations. This plan has been followed because it is essential in digestion trials that the animals eat all the feed that is offered them, without leaving any waste whatsoever.

Tables giving the digestible nutrients in various feeds, such as Appendix Table I of this volume, must consequently be computed from these digestion coefficients, since they are the only ones available. It must therefore be borne in mind that well-fed dairy cows will really secure from the feeds they eat slightly smaller amounts of nutrients than are shown in Appendix Table I. This fact is, however, fully taken into consideration in the recommendations made in the Morrison feeding standards for dairy cows. This has been done by placing the advised amounts of nutrients slightly above the theoretical requirements, to cover the decrease in digestibility when liberal rations are fed.

In certain feeding standards for dairy cows no such correction factor has apparently been applied. As a result, dairy cows will be under-fed, if rations are computed according to these standards and with the available figures for the digestible nutrients in various feeds.

1013. Requirements for maintenance.—The Morrison feeding standards recommend from 0.60 to 0.65 lb. digestible protein and 7.0 to 7.9 lbs. total digestible nutrients for the maintenance of a 1,000-lb. cow. Stated in terms of net energy for those who may wish to compute rations on this basis, the requirement for such a cow is 5.6 to 6.3 therms of net energy. The amounts of nutrients recommended for other live weights have been computed on the basis that maintenance requirements are proportional not to the live weight, but to the 0.87 power of the live weight.

This factor was selected because it was believed that the maintenance needs were not strictly proportional to live weight, for the reasons discussed in an earlier chapter. (**238**) By using the 0.87 power of the live weight instead of some other factor, rations computed according to the standards seem to agree best with good dairy practice.

In making the recommendations in these standards for the maintenance of dairy cows, the author has carefully considered the extensive investigations of Hills and associates at the Vermont Station over a period of 14 years,[18] and also the earlier studies of Haecker,[19] and the investigations of Eckles,[20] of Armsby,[21] of Forbes and associates,[22] of Brody and Proctor,[23] and of Möllgaard and Hansson.[24]

A special committee of the National Research Council has presented "Recommended Nutrient Allowances for Dairy Cows."[25] In these standards no range is given in the amount of digestible protein and of total digestible nutrients advised. The amounts of digestible protein recommended for maintenance are approximately the same as the lower set of fig-

ures in the Morrison standards, and the amounts of total digestible nutrients similar to the higher set of figures in the Morrison standards.

From studies in New Zealand, McMeekan has estimated that cows on pasture need about 50 per cent more total digestible nutrients than barn-fed cows.[26] This is because of the work done in travelling about the pasture and in gathering their food.

1014. Requirements for milk production.—Extensive investigations have been conducted to determine the amounts of nutrients cows need, in addition to their maintenance requirements, for the production of milk. These investigations have been carefully considered in drawing up the recommendations in the Morrison feeding standards. For those especially interested in the nutrient requirements of dairy cows, somewhat detailed information concerning the studies on this subject is given in articles which follow.

The investigations have proved that fairly good production can be secured when cows receive in their feed, in addition to the allowance for maintenance, only about 1.25 times as much digestible protein as the amount of protein in the milk they produce. However, cows of good productive capacity may yield somewhat more milk and fat when the protein allowance is greater than this. Supplying, in addition to the maintenance needs, more than 1.50 to 1.60 times as much digestible protein as there is protein in the milk, does not increase the milk yield appreciably.

In the Morrison standards the lower figures in the range of allowances for digestible protein provide only about 1.25 times as much digestible protein as the amount of protein in the milk. The higher figures in the range of allowances supply about 1.5 times as much digestible protein as there is protein in the milk.

The author believes it is the best plan under usual conditions to feed cows capable of producing 1 lb. or more of butterfat a day, according to the more liberal recommendations. If protein-rich feeds are unusually expensive, it may be most economical, even in the case of good cows, to supply no more than the lower amounts of protein shown in the standards.

1015. Investigations on protein requirements.—Haecker of the Minnesota Station was apparently the first scientist to appreciate that the nutrient requirements of dairy cows depended not only on the amount of milk produced, but also upon its richness. Milk that is rich in fat is also considerably higher in protein than that which has less fat. Haecker therefore recommended in his feeding standards not only a greater amount of total digestible nutrients but also a greater amount of digestible protein for each pound of milk rich in fat than for milk lower in fat.

The Haecker standards recommended 0.7 lb. digestible protein daily per 1,000 lbs. live weight for maintenance and, in addition, amounts for each pound of milk which provided about 1.5 times as much digestible protein as the amount of protein in the milk.[27] These protein recommendations were much lower than the old Wolff-Lehmann feeding standards, which advised nearly twice as much digestible protein as the milk of average composition.

The recommendations in the Armsby standards, the Eckles standards, the Möllgaard standards, and the Hansson standards, which are based on digestible true protein, must be converted into digestible crude protein (called digestible protein in this volume) to compare them with the standards previously discussed. When this is done and the amounts of protein recommended for maintenance are added to the amounts for milk production, it will be found that about the same amounts of protein were advised in the Armsby standards as in the Haecker standards.[28] Somewhat greater amounts were recommended in the Hansson standards, the Möllgaard standards, the Eckles standards, and also in the standards presented by Ellett, Holdaway, and Harris of the Virginia Station.[29]

In extensive investigations by Hills and associates at the Vermont Station, mostly with grade Jerseys, the cows produced satisfactorily on rations providing 1.26 to 1.46 times as much digestible protein, in addition to maintenance, as the milk contained.[30] The yield on such rations was nearly as high as on a more liberal protein supply. However, the cows were not high producers, as they yielded only 0.78 to 0.92 lb. fat daily, on

the average. With such cows the production was not seriously reduced when rations still lower in protein were fed.

It was found in Wisconsin and Pennsylvania metabolism experiments that cows of fairly good production will remain in nitrogen balance (without losing protein from their bodies) if the ration provides, in addition to maintenance needs, 1.25 times as much digestible protein as the milk contains.[31]

In New York experiments cows fed early-cut mixed clover-and-timothy hay and corn silage for roughage produced a daily average of 33.1 lbs. milk (equated to a basis of 3.5 per cent fat) when fed a concentrate mixture containing 16 per cent total protein.[32] The average yield of other cows fed a concentrate mixture having 20 per cent protein was 34.4 lbs. The ration lower in protein furnished, in addition to maintenance needs, 1.2 to 1.4 times as much digestible protein as was contained in the milk, and the latter ration about 1.7 times as much. Though the average yield of milk was slightly greater on the 20-per-cent-protein mixture, the difference was too small to be statistically significant.

In these experiments a concentrate mixture having 24 per cent total protein did not produce any more milk or fat than did the 20-per-cent mixture, when fed with the first-class mixed hay and corn silage. On the other hand, the milk yield was decidedly decreased and the digestibility of the ration was much lower when a concentrate mixture was fed that had only 12 per cent protein. After deducting 0.6 lb. digestible protein daily per 1,000 lbs. live weight for maintenance, this ration did not supply quite as much digestible protein as was contained in the milk.[33] The cows fed this ration therefore had to draw on their bodies for some of the protein they put into their milk.

In similar Ohio experiments, in which cows were fed good mixed legume-and-grass hay and corn silage for roughage, the yield of milk was 6 per cent greater on a concentrate mixture having 19.0 per cent total protein than on one with only 13.8 per cent.[34] The first ration supplied, in addition to the maintenance needs, about 1.5 times as much digestible protein as the milk contained, and the lower-protein ration about 1.25 times as much.

In experiments by the United States Department of Agriculture cows fed a concentrate mixture having only 10 to 12 per cent protein, with timothy hay, corn silage, and a little alfalfa hay for roughage, produced as much milk as when fed a concentrate mixture having more protein.[35] The low-protein ration supplied only 1.25 times as much digestible protein as in the milk in addition to a maintenance allowance of only 0.5 lb. digestible protein daily per 1,000 lbs. live weight. Differing from this result, in a previous experiment the milk production was much less on such a low-protein ration than on a ration having more protein.[36]

In certain other studies rations furnishing even more protein than recommended in the higher set of figures in the Morrison standards have tended to produce a little more milk than rations having less protein.[37]

In Ohio experiments cows of high productive capacity yielded a surprising amount of milk when fed even less than 1.25 times as much digestible protein, in addition to maintenance, as their milk contained. On a low-protein ration having a nutritive ratio of 1 : 11, Holstein cows produced as much as 11,013 lbs. of 4 per cent milk in a year.[38] However, the yield was much less than from the same cows when fed rations containing an adequate supply of protein. On the protein-poor ration the digestibility of the feed was also considerably decreased. It was therefore necessary to feed very liberal amounts of concentrates to secure fair production. The cows lost about 200 lbs. in weight during milk production, but regained their original weights during the dry period.

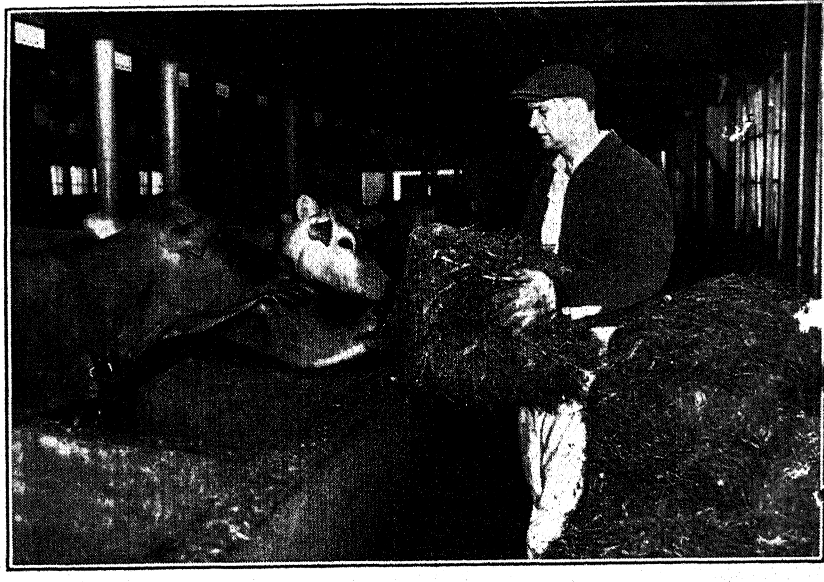
In the Ohio experiments other cows were fed rations extremely rich in protein, having a nutritive ratio of 1 : 2. There were no marked injurious effects from this great excess of protein, although there was a tendency toward delayed breeding on this ration and a longer period than normal between calvings.

The amounts of digestible protein recommended by the special committee of the National Research Council, for the production of milk of the various fat percentages are between the lower and

upper sets of figures in the Morrison standards.[25]

1016. Importance of protein content of the roughage.—The percentage of protein that is needed in the concentrate or grain mixture to make a properly-balanced ration will depend on the protein content of the roughage that is fed. When the only roughage is alfalfa hay, soybean hay, or cowpea hay (all of which are very rich in protein), the is not actually needed. Also, as is shown later, it is wise to add a phosphorus supplement to such a ration. (1035)

The amount of protein supplied by the roughage will be somewhat less when red clover hay is fed instead of alfalfa hay. However, a ration of 24 lbs. of good clover hay and 12 lbs. of corn grain provides enough protein for a cow producing about 40 lbs. of 3.5 per cent milk daily.



PROTEIN CONTENT OF ROUGHAGE IMPORTANT

The percentage of protein that is needed in the concentrate or grain mixture depends on the protein content of the roughage that is fed. (From New York State College of Agriculture, Cornell University.)

amount of protein supplied by the hay will be so large that there will be plenty for a cow of good productive capacity, when merely corn grain or a mixture of corn and other grain is fed with the hay.[39]

For example, a ration of 24 lbs. of average alfalfa hay and 18 lbs. of corn grain will furnish sufficient protein for a 1,200-lb. cow producing 60 lbs. of 3.5 per cent milk. For high-producing cows it may be wise to include wheat bran or some other protein-rich concentrate to make the mixture more palatable, even though the additional amount of protein

Since young, actively growing pasture plants are fully as rich as legume hay in protein, on the dry basis, it is unnecessary to use a concentrate mixture high in protein for cows on excellent pasture. This matter is discussed further in Chapter XXVI.

When non-legume roughage, such as corn or sorghum silage, is fed along with legume hay, or when the hay is mixed legume-and-grass hay, considerably less protein will obviously be supplied by the roughage. The concentrate mixture must then be richer in protein than when pure legume hay is the only roughage. How-

ever, less protein is needed in the concentrate mixture under such conditions than many dairymen believe necessary.

Many different concentrate mixtures are given in Appendix Table VII which are well adapted for use with various types of roughage. These example formulas will be helpful in deciding what kind of a mixture to feed under one's local conditions.

If good alfalfa hay and corn silage are full-fed for roughage, such a grain mixture as one-half ground corn and one-half ground oats is satisfactory for cows yielding about 1.0 lb. of butterfat a day. For higher-producing cows and when the amount of alfalfa hay is limited, protein supplements should be added to the ration.

Several experiments have shown clearly that no protein supplement is needed when cows of any usual rate of production are fed plenty of alfalfa hay and corn silage with a grain mixture of corn and oats.[40] In these trials the milk yield was fully as high on the home-grown ration as when protein supplements, such as linseed meal, soybean oil meal, or cottonseed meal, were added.

Dairy cows yielding 1.25 lbs. of fat a day remained in nitrogen balance, losing no protein from their bodies, in metabolism experiments at the Wisconsin Station when fed a ration of alfalfa hay, corn silage, and grain.[41] On the other hand, they lost protein when clover hay, lower in protein than alfalfa, was substituted for the alfalfa hay.

That very high milk production can be secured without any protein supplement, when abundant protein-rich roughage is fed, is well proved by the results achieved by an Illinois dairyman.[42] His herd averaged 525 lbs. of fat a year on home-raised feed, without any protein supplement whatsoever. The cows were fed a grain mixture of half corn and half oats at a moderate rate. In winter they had for roughage all they would eat of legume hay and legume-grass silage. In summer they were on first-class pasture and had a little hay in addition.

1017. Wasting protein supplements with legume hay.—Often, when dairymen who have been growing but little legume hay change their cropping practices and provide their cows with an abundance of good legume hay, they fail to reduce the amounts of protein supplements in the concentrate mixtures they feed. For example, in the northeastern states some dairymen continue to feed concentrate mixtures containing as much as 20 to 24 per cent total protein, after they have provided their cows with plenty of alfalfa hay. Since protein supplements, such as soybean oil meal and linseed meal, are usually higher in price than the cereal grains or other low-protein concentrates, this is then decidedly uneconomical. The cows would produce just as much milk and fat if only sufficient amounts of protein supplements were fed to balance the ration.

Even with good mixed hay for roughage, smaller amounts of protein supplements are needed than have been fed by many dairymen, especially in the eastern states. The experiments which have previously been reviewed show that with such roughage a concentrate mixture containing 16 to 18 per cent of total protein furnishes sufficient protein for satisfactory production. When protein supplements are high in price, a mixture containing only 16 per cent protein will generally be more economical with such roughage than one higher in protein. It must be borne in mind, however, that with mixed hay containing only a small proportion of clover or that which is late-cut, somewhat more protein than this should be supplied in the concentrate mixture.

It is interesting to note that when a concentrate mixture unnecessarily high in protein is fed with legume hay, often the cows do not clean up the leaves well. Their instinct seems to let them know that they do not need the protein-rich leaves. If a concentrate mixture lower in protein is later fed, the cows are then apt to eat all the leaves.

1018. Quality of protein.—It has been shown in Chapter V that the kind or quality of protein in rations for milk cows is of little importance when the rations contain good roughage and are

made up of feeds that are otherwise satisfactory. (127) This is because the bacteria in the paunch of ruminants make complete proteins, containing all the essential amino acids, from proteins of poor quality and even from simpler nitrogenous substances. Further on in the digestive tract, ruminants digest the bacteria and thus use the bacterial protein which has been formed.

In 5 experiments at the New York (Cornell) Station with high-producing cows fed corn silage and mixed hay low in legumes for roughage, a concentrate mixture having poor-quality protein gave as good results as a mixture having better-quality protein and also more variety.[43] The first mixture consisted of corn gluten feed, corn gluten meal, ground corn, and ground oats, with molasses in 2 of the tests. The mixture with better-quality protein had soybean oil meal, linseed meal, cottonseed meal, distillers corn dried grains, corn gluten feed, ground corn, and ground oats, with or without molasses. For swine or poultry this mixture would unquestionably have given better results than the first one.

Similarly, in a Wisconsin experiment dairy heifers grew just as well when gluten meal was used to balance a ration of corn silage, timothy hay, corn, and oats, as when the supplements were linseed meal and wheat bran.[44] Also, the growth was about as rapid on the rations with no legume hay as when alfalfa hay was fed.

When the roughage is of poor quality, then the kind of protein in the concentrate mixture may be of importance. For example, in a Wisconsin metabolism experiment corn gluten feed was inferior to protein supplements having protein of better quality, when fed with cereal grain and with corn stover as the only roughage.[45] On the other hand, when the roughages were clover or alfalfa hay and corn silage, corn gluten feed was nearly as efficient a protein supplement as linseed meal, cottonseed meal, or distillers dried corn grains.

Similarly, in metabolism experiments in Scotland the protein of a ration containing grass silage or fresh or dried young grass was more efficient for milk production than the protein of a ration with no good roughage.[46] As shown later, urea gives much better results when substituted for part of the protein in a ration with good roughage than when the roughage is poor. (1019) A possible reason for the different results with good roughage and with poor roughage has been mentioned in Chapter V. (127)

1019. Urea as a protein substitute.—The use of urea as a substitute for part of the protein in rations for ruminants and the conditions affecting its utilization have been discussed in Chapter V. (129) Many experiments have been conducted to determine the value of urea in dairy rations.[47] In some of the trials the results have been entirely satisfactory with urea as a partial protein substitute, while in other trials rations balanced with ordinary protein supplements have been somewhat superior.

For example, in Virginia trials urea was an effective substitute for cottonseed meal in rations for dairy cows. In contrast, in English experiments on 12 farms the addition of peanut oil meal to a low-protein ration significantly increased milk production, while the addition of urea had little effect.

In trials in Hawaii, Massachusetts, and New York the milk yield was appreciably less when urea replaced soybean oil meal or other protein supplements in the concentrate mixture. When continued on a concentrate mixture containing urea for a considerable time, the cows have tired of the mixture in some trials.

Urea is utilized best when it is fed in combination with grain or some other starchy concentrate. Molasses is not a satisfactory substitute for all the grain. Also, urea gives better results when used in a ration with good roughage than when all the roughage is poor. In New York trials dairy heifers did poorly on a ration of molasses, urea, and late-cut grass hay, while the gains were satisfactory when soybean oil meal was fed as a protein supplement. The results were somewhat better when a little ground corn

was added to the molasses, urea, corn, and hay ration, and were satisfactory when the poor hay was replaced by good mixed hay furnishing considerable protein.

We may conclude that urea is a useful substitute for part of the protein supplements in a concentrate mixture for dairy cows, when there is a shortage of protein supplements or when they are very high in price. However, urea-containing concentrate mixtures are never superior to mixtures in which the same amount of nitrogen is supplied by ordinary protein supplements, and the urea mixtures may not be quite so efficient.

1020. Fat in dairy rations.—It has been shown in Chapter X that the fat in milk can be made from other food nutrients than fat, but that an animal can apparently make milk fat more readily from food fat than by synthesizing it from carbohydrates. Therefore, unless the ration for a high-producing cow contains at least a certain minimum amount of fat, the yield of milk and of butterfat will be decreased. (**303**)

Dairy rations now often have less fat than formerly, because of the increased use of the solvent process in the production of soybean oil meal and other oil meals. It is therefore important to know how this lower fat content of the ration affects the milk yield.

The most extensive investigations on this problem are 17 experiments at the New York (Cornell) Station.[48] In these trials low-fat concentrate mixtures having an average of only 2.7 per cent fat were compared with higher-fat mixtures averaging 6.5 per cent in fat. These mixtures were fed with such roughages as timothy or mixed hay plus corn silage or dried beet pulp. On the average, the yield of 4-per-cent milk was 1.4 lbs., or 4 per cent, greater on the high-fat concentrate mixtures. It was concluded that 100 lbs. of a concentrate mixture having 4 per cent fat would produce as much milk as 104 lbs. of a similar mixture with only 2 per cent fat.

When a concentrate mixture containing 4 per cent fat was fed with corn silage and mixed clover and grass hay for roughage, the ration supplied about 70 per cent as much fat as there was in the milk. Somewhat more than 30 per cent of the milk fat was therefore made from other nutrients in the ration, for part of the so-called "fat" in feeds consists of other substances than true fats. (**12**)

These experiments, together with other studies and the experience of dairymen in recent years, show that good milk production, if not quite maximum yields, can be secured on concentrate mixtures containing only 2.5 per cent fat.[49] However, a concentrate mixture having more fat is worth slightly more per ton. In the New York experiments it was found that the difference in yield due to a low fat content of the concentrate mixture was less when abundant good roughage was fed. Also, adding soybean oil or corn oil to a low-fat ration was not nearly so beneficial as supplying the same amount of fat in natural feeds.

When by-product animal fat is available at a price that makes its use for stock feeding economical, such fat can be added by manufacturers of formula feeds to increase the fat content and energy value. (**134**) For example, in a recent Arizona trial the milk and fat production was slightly increased when 7 per cent of stabilized animal fat was added to a low-fat dairy concentrate mixture of rolled barley, dried citrus pulp, molasses, and cottonseed meal.[50]

1021. Total digestible nutrients or net energy for milk production.—In the Morrison feeding standards a range is given in the amounts of total digestible nutrients and of net energy recommended, in addition to the maintenance needs, for each pound of milk of the various fat percentages. The recommendations for milk containing various percentages of fat have been computed on the basis of the Gaines' formula for estimating the energy content of milk. (**999**)

In the opinion of the author, the estimated net energy values given in Appendix Table II are a more accurate basis for computing rations for milk production than the total digestible nutrient

values in Appendix Table I. This opinion has been corroborated by recent investigations in which cows have been fed various proportions of hay and concentrates.[51]

Where experiments have definitely shown that a particular feed, such as oats or wheat bran, has a higher value for milk production than it does for meat production, separate net-energy values are given for milk production.

The higher amounts of total digestible nutrients and of net energy stated in the standards are advised under most conditions. To meet these recommendations it is necessary, in the case of cows producing good yields of milk, to feed considerable amounts of concentrates, in addition to a liberal supply of roughage. The grain feeding tables (Appendix Table VIII) show the amounts of concentrate mixture, or grain mixture, needed to meet these recommendations for cows producing different amounts of milk when the roughage supply is very liberal, average, and scanty.

If one wishes to secure maximum yields from a cow capable of high production, even more concentrates must be supplied than called for by these recommendations. Also, when milk is very high in price in comparison with the cost of concentrates, more liberal concentrate feeding may be profitable.

On the other hand, when roughages are very cheap in comparison with concentrates, then it will be most profitable to supply no more total digestible nutrients than called for in the lower figures of the standards. When good cows are thus fed, their milk yield will decline more rapidly during lactation than when their nutrient supply is more liberal, and their total yield for the year will be considerably less. Nevertheless, such feeding may produce a greater net return when concentrates are very expensive. It is pointed out later in this chapter that in districts where alfalfa hay is very cheap, compared with grain or other concentrates, it may be most profitable to feed an abundance of hay and no concentrates whatsoever, even to good cows. (**1027**)

Cows need additional nutrients during the latter part of lactation and in the dry period, to provide for the development of the unborn calf and to get the cow into good condition before calving. (**1082**) For the last 2 or 3 months before calving, the amounts of nutrients shown in the feeding standards under "C. Additional allowance for last 2 to 3 mo[illegible] of pregnancy" should be added to [illegible] lowance for maintenance and the [illegible] ance for milk produced.

Since milking heifers are stil[illegible] ing, they need the additional am[illegible] feed stated under "Extra feed for [illegible] heifers," in the articles immedia[illegible] ceding Appendix Table III.

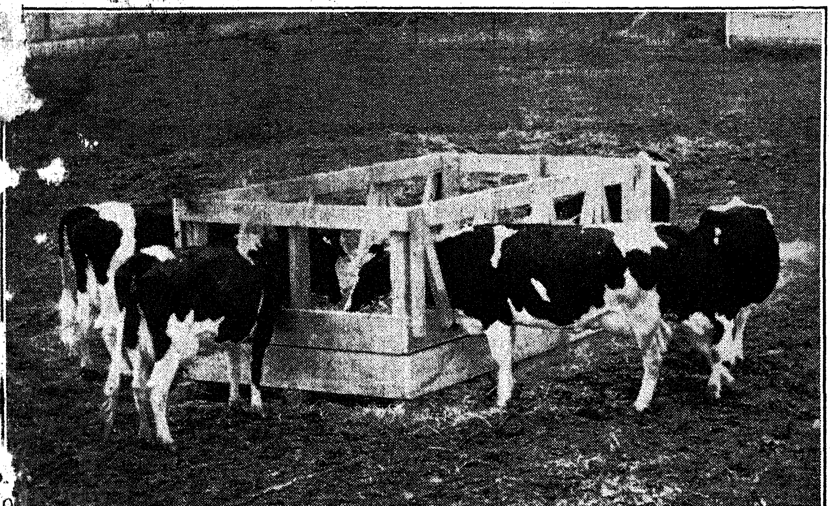
In making the total digestible [illegible] trient and net energy recom[illegible] in the Morrison standards, the variou[illegible] vestigations on this subject have been carefully considered, especially the studies of Brody of the Missouri Station and Gaines of the Illinois Station.[52] In the report of the special committee of the [illegible] tional Research Council, which has [illegible] mentioned previously, approximatel[illegible] same allowances of total digestible [illegible] trients are advised per pound of m[illegible] as the higher set of figures in the Mo[illegible]ison standards.[25] In that report no net energy recommendations are made.

1022. Abundance of high-quality roughage saves concentrates.—In order to secure the greatest net returns in dairying, one of the first essentials under usual conditions is to provide the [illegible]s with an abundance of first-class roughage. If cows are furnished all the high-quality roughage they will eat, they consume considerably more than they [illegible]ld of poorer roughage. High-quality roughage, such as well-cured legume hay or corn silage, is also richer in digestible nutrients than poorer roughage, such as ordinary grass hay. Therefore, when cows have an abundance of good roughage, they will get from the roughage a much larger proportion of the nutrients they need for high production, than when the roughage is poor or scanty in amount.

For example, Grain Feeding Table A (Appendix Table VIII) shows that when a cow yielding 40 lbs. of 3.5 per

cent milk daily is fed good roughage very liberally she needs only 9.6 lbs. of concentrate mixture a day. However, if she is fed poor roughage or a scanty amount of good roughage she may need about 15.2 lbs. of concentrates. Similarly, if this cow is on excellent pasture she will need only about 6.0 lbs. of concentrates to maintain high production, while over ... as much will be needed on fair ... tain ... su ... amo ...

During 4 years, the average yield of milk on twice-a-day milking was 12,347 lbs. and the average yield of fat 410 lbs. The fat average was 400 lbs. or over each year. To secure this high yield, the cows received an average of 4,035 lbs. hay and 8,093 lbs. corn silage, were on pasture an average of 160 days, and were fed an average of only 2,577 lbs. grain mixture. The rate of grain feeding was much lower than usual in this intensive



AN ABUNDANCE OF ROUGHAGE SAVES CONCENTRATES

When the supply of forage on pasture is scanty, cows should be fed hay or silage in addition, so they can get their fill of roughage. A rectangular rack reduces waste and may be used for feeding either hay or silage. (From New York State College of Agriculture, Cornell University.)

The excellent production that can be secured when well-bred cows have an abundance of high-quality roughage and a moderate amount of concentrates is well shown by the records made by a dairyman in a New York dairy-herd improvement association.[53] The cows in this herd, which were chiefly Holsteins, had all they would eat of good legume or mixed hay and corn silage during the barn-feeding season. In summer excellent pasture was provided on well-fertilized fields. Whenever the pasture became at all scanty, silage or silage and hay were fed in addition. Thus the cows were filled up with high-class roughage throughout the year.

dairy district, being 1 lb. of grain mixture for each 4.8 lbs. of milk. For the 4-year period the average annual cost of feed per cow was $89.50; the average value of product, $285.25; and the average net income over feed cost $195.75.

A New Hampshire dairyman who made full use of pasture and hay mixtures containing Ladino clover secured as large a milk yield as this, with even less concentrates.[54] Though he fed an average of only 1,220 lbs. of grain mixture per cow per year, he obtained an average of 13,030 lbs. milk and over 400 lbs. of fat. This was made possible by feeding in winter an abundance of early-cut, high-quality hay, along with silage,

and providing excellent pasture on well-fertilized fields throughout the growing season. Before he used the efficient, new-type pasture and hay mixtures, he fed over twice as much grain mixture a year, but the average milk yield was less.

1023. Good roughage cannot entirely replace concentrates.—The needs of good cows for total digestible nutrients and net energy cannot be fully met by supplying only an abundance of roughage, without the feeding of any grain or other concentrates. This is true even when they have the best of pasture during the growing season and are fed an abundance of good hay and silage the rest of the year.

If cows capable of high production are fed only roughage of any ordinary quality, they will produce decidedly less milk than when fed the usual amount of concentrates in addition. This is first of all because such roughage is so bulky and so low in total digestible nutrients and net energy that a cow cannot eat enough such feed to supply the amount of nutrients required for high production.

When the ration does not furnish enough net energy to meet the needs for maintenance and for the amount of milk a cow is yielding, she can draw on her body stores for a brief time, provided that she is in good condition of flesh. However, her milk yield will soon fall to the level that is permitted by her nutrient intake.

If the roughage is of superlative quality and is fed in abundance, so the cows can select only the leaves or other finer and more nutritious parts and leave the stems, such roughage alone may produce nearly as much milk as when concentrates are fed in addition. In a 5-year New Jersey experiment cows were fed in winter unusually good alfalfa hay (U.S. No. 1 extra green and leafy, second and third cutting) and well-eared corn silage.[55] The hay was fed 4 times a day in greater amounts than the cows would eat, so they could leave the stems. In summer the cows were grazed on excellent legume-grass pasture in a high state of fertility and were fed the excellent hay in addition.

On this unusually excellent supply of roughage, without any concentrates, cows produced 81.5 per cent as much fat-corrected milk a year as others that were fed concentrates in addition at the rate of 1 lb. of concentrate mixture per 3 lbs. of milk. Other cows fed concentrates at the low rate of 1 lb. for each [illegible] lbs. of milk produced 94.5 per cent as much milk as those fed concentrates more liberally.

1024. Is there a lactation factor?—Opinions of scientists differ as to whether the deficiency of net energy in a ration of roughage alone for dairy cows is the only cause of the lower production on such rations. From their Michigan experiments Huffman and associates have concluded that most concentrates and certain other feeds supply an unknown "lactation factor or factors" needed for high milk production.[56] In the experiments, after cows had declined in milk production on alfalfa hay alone, part of the hay was replaced by an amount of grain or other feeds which furnished the same amount of total digestible nutrients. In most cases the milk yield increased appreciably. Similar results were secured in Oregon and West Virginia trials, and in an Arizona experiment dried grapefruit pulp increased milk production of cows previously fed alfalfa alone more than did an equal amount of the usual type of concentrate mixture.[57]

When grain or other concentrates replaced part of the hay on an equal total-digestible-nutrient basis in these trials, the ration of course had more net energy, and this could well have been the cause of the increase in milk production. However, in the later Michigan experiments the substitution was made on an equal net energy basis, but the milk yield again seemed to be increased in most cases.

In the Michigan trials early-cut hay of high quality seemed to be higher in the lactation factor than ordinary hay. Well-eared corn silage apparently supplied more of the factor than corn silage with little grain. However, excellent

early-cut hay has more net energy per pound of total digestible nutrients than does ordinary hay, and well-eared corn silage much more than silage with few ears.

The results of Maryland and New York experiments differ from those of the Michigan investigations.[58] In trials with cows whose milk yield had declined on hay alone, the production was not increased when part of the hay was replaced by an amount of concentrates that furnished equal net energy. The investigators therefore concluded that the increase in yield that occurs under usual conditions when concentrates are added to hay alone could be explained chiefly or entirely on the net energy basis.

From the practical standpoint, no matter whether or not there is an unknown lactation factor which is required for high milk production, all agree that maximum milk yield cannot be secured on only roughage of any usual quality. Also, there is agreement that excellent, early-cut hay will produce more milk than ordinary hay, and that well-eared, well-matured corn silage is superior to silage with few ears.

1025. Determining the most profitable level of concentrate feeding.—Determining the most profitable amount of concentrates to feed dairy cows in addition to an abundance of good roughage is one of the most important problems of dairying. The answer will depend on the relative cost of nutrients in roughages and concentrates, on the price received for the milk, and on the productive capacity of the cows. Many experiments have been conducted to study this problem, of which the most extensive were the "input-output" experiments conducted by the United States Department of Agriculture in cooperation with 10 state experiment stations.[59]

These and other investigations have shown that when cows capable of good production are changed from the usual method of feeding to roughage alone, fed in abundance, they will usually yield only about 75 per cent as much milk and fat as on a normal ration. If continued on roughage alone for consecutive years, their yield will drop still further. This is because they tend to run down in condition, or because they become depleted of the "lactation factor" mentioned previously.

When various amounts of concentrates, or grain mixture, are added, step by step, to a plentiful supply of roughage, the milk yield of a good cow will be increased until her full capacity is reached. However, the "law of diminishing returns" operates in determining the amount of additional milk that will be secured from the successive additions of concentrates. This means that more additional milk is obtained, per 100 lbs. of concentrates added, from the first few hundred pounds of concentrates fed a year, than from further additions. Constantly decreasing amounts of additional milk are secured, per 100 lbs. of concentrates added, as the level of concentrate feeding is increased.

The feeding of greater amounts of concentrates will not only produce more milk, but will also reduce the amount of hay and other roughage that the cow can consume in a year. Usually, the amount of total hay equivalent, including pasture, saved by each pound of concentrates added per day will range between 0.5 and 0.8 lb. The amount of hay equivalent saved per pound of additional concentrates seems to increase slightly as the level of concentrate feeding is raised, instead of decreasing like the additional yield of milk. This is probably because the total capacity of the cow for holding feed is being approached.

1026. Effect of successive additions of concentrates.—From the results of the cooperative "input-output" experiments, careful estimates were made of the effect produced by successive additions of concentrates to all the roughage cows would consume. Some of these estimates are given in the table on the next page. The cows averaged 1,142 lbs. in weight. Their average yield was 8,919 lbs. of 4 per cent fat-corrected milk in previous lactations when fed concentrates and roughages in accordance with usual dairy practice.

The table shows that as the level

of concentrate feeding is increased, the amount of additional milk secured per pound of concentrate added steadily decreases. About 1.3 lbs. of additional milk (on the 4 per cent fat-corrected basis) are obtained when a small amount of concentrates is added to all the roughage a cow will eat. The amount of additional milk secured per pound of concentrates added steadily falls. When cows are fed an unusually large amount of concentrates, only about 0.3 lb. more milk is secured per pound of additional concentrates.

the latter part of lactation and the dry period for the development of the calf, they lost weight and ran down in condition. On the other hand, when cows had at all times all the good roughage they wanted and were in good flesh at calving, they produced well if fed according to the Haecker standards during the lactation period.

In these studies there were no significant differences between the heavy and light rates of concentrate feeding in the health and reproduction of the cows, except there was more trouble from the cows going "off-feed" when fed heavily on concentrates.

Effect of adding increasing amounts of concentrates to dairy rations

Concentrates fed per year	Hay equivalent fed per year	Estimated yield of 4 % milk	Additional milk per lb. concentrates added	Decrease in hay equiv. per lb. concentrates added
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	11,338	6,438	......	......
450	11,048	7,020	1.3	0.6
900	10,751	7,517	1.1	0.7
1,350	10,447	7,947	1.0	0.7
1,800	10,136	8,317	0.8	0.7
2,250	9,817	8,639	0.7	0.7
2,700	9,492	8,915	0.6	0.7
3,150	9,159	9,156	0.5	0.7
3,600	8,818	9,366	0.5	0.8
4,050	8,471	9,550	0.4	0.8
4,500	8,116	9,708	0.4	0.8
4,950	7,754	9,847	0.3	0.8
5,400	7,385	9,971	0.3	0.8

The table shows that at the lower levels of concentrate feeding each pound of concentrates saved about 0.7 lb. of hay equivalent. At the highest levels of concentrates, the amount of hay equivalent consumed was reduced about 0.8 lb. for each additional pound of concentrates.

At the level of 2,250 lbs. concentrates annually, the cows received a trifle more total digestible nutrients a year than the total advised for maintenance and milk production in the Haecker standards. At the highest level of concentrates, the annual total digestible nutrient intake was about 16 per cent above the Haecker standards.

When cows were fed strictly according to the Haecker standards, with no pasture and no additional feed during

One reason why the law of diminishing returns applies when different levels of concentrates are fed is that at higher levels of concentrate feeding the digestibility of the ration is slightly decreased and the net-energy value decreased still more. (**101**, 78) After making a critical study of the results of the input-output investigations, Reid of Cornell University has recently pointed out that some of the difference in amount of milk produced per pound of added concentrates at the higher levels of concentrate feeding and at low levels can be accounted for by the following: [60] On the low levels the cows lost weight, thus drawing on their bodies for some of the

energy in the milk they produced. At the higher levels they maintained their weights or even gained. The loss in weight on scanty feeding could not continue for successive years, but the milk production would decline to the amount permitted by the nutrient intake.

In the "input-output" studies at certain of the experiment stations some cows were fed all the concentrate mixture they would eat, being brought gradually up to full feeding. For example, in the Pennsylvania tests Holstein and Brown Swiss cows ate an average of 24.6 lbs. concentrates a day throughout the lactation period. The highest amount was 39 lbs. during the peak of production. When thus fed by skilled herdsmen, the cows remained in good health. Though the milk yield was increased somewhat by such heavy feeding of concentrates, the added amount secured per pound of additional concentrates fed was too small to be profitable under any usual conditions.

1027. The most profitable level of concentrates.—Good judgment and experience are necessary to determine the most profitable level of concentrates to feed in any herd, in addition to an abundance of good roughage. The data in the preceding table indicate the approximate amounts of additional milk secured per pound of added concentrates, at various levels of feeding. Also, one must consider the saving in roughage as the amount of concentrates is increased. Any dairyman who is in doubt as to the best level of feeding to use under his local conditions should consult his county agricultural agent or ask for further information from his state agricultural college.

In the corn belt and eastward it is generally most profitable to supply good cows with enough concentrates, in addition to an abundance of high-quality roughage, to meet the recommendations of the feeding standards. When milk is high in price, in comparison with concentrates, it may pay to feed cows of high productive capacity somewhat more concentrates than called for in the higher set of figures in the Morrison standards. In other words, it may pay to feed more concentrates than stated in the grain feeding tables in Appendix Table VIII. Such heavy feeding is advisable only for an experienced dairyman, who watches his cows closely to prevent their going "off-feed" from receiving an excessive amount of concentrates.

At the other extreme, in such regions as some of the alfalfa districts of the West, alfalfa hay may be so cheap in comparison with concentrates that it will be most profitable to feed much less concentrates than called for by the feeding standards. Under these conditions, it may even be most economical to use no concentrates whatsoever, but to feed the cows only hay and other roughage, with pasture in summer. When milk is high in price, it pays even under such conditions to feed some concentrates, in order to secure a larger yield.

When an abundance of high-quality roughage is provided, only a very moderate rate of concentrate feeding may be most profitable and may produce as much or nearly as much milk as more concentrates. For example, in an Ohio experiment cows were fed in winter all the good alfalfa hay they would eat, with corn silage in addition.[61] In summer they had first-class pasture. When fed about as much grain mixture as advised in Appendix Table VIII for "very liberal feeding of good roughage," cows produced, on the average, fully as much milk as cows fed considerably more grain mixture. First-calf heifers placed on the moderate rate of concentrate feeding tended to yield less milk the first year than those fed more liberally, but in the following lactations they produced more than the cows fed larger allowances of grain mixture.

1028. Milk production on roughage alone.—Several experiments have been conducted, especially by western experiment stations, to determine how much milk and fat good cows would yield on roughage alone.[62] The actual production on such rations will differ considerably, depending on the quality of the hay or other roughage, the size and productive capacity of the cows, and on whether a

phosphorus supplement is provided to ensure an ample supply of this mineral nutrient.

From a study of the results of such experiments conducted by the United States Department of Agriculture and western state experiment stations, Woodward reached the following conclusions.[63] On a ration of only good alfalfa hay, plus a phosphorus supplement if needed, good cows milked twice a day will yield about 0.8 lb. of butterfat a day, as an average for the lactation period, or approximately 250 lbs. of fat a year. When corn silage is fed in addition to alfalfa hay, the annual yield of fat will be increased to about 275 lbs. If the cows have first-class pasture in addition during the growing season, it is possible to increase the yield to 300 lbs. of fat a year. He states that these yields should be considered maximum, rather than average, because the quality of both the hay and the pasturage was somewhat above average in the experiments upon which the estimates were based.

Because of the widespread use of hay-crop silage for dairy cattle, it is important to note that higher milk production cannot apparently be maintained on hay-crop silage alone than on hay alone. In a recent Indiana test Holsteins that had been producing 45 to 50 lbs. of milk a day, dropped rapidly to 25 to 30 lbs. when fed only alfalfa silage.[64]

In the southern states good pasture can, with proper fertilization and good management, be provided during most of the year. Under such conditions higher milk yields can be secured without concentrates than in colder regions where cows cannot be pastured in winter. For example, at the West Tennessee Station, Jersey cows fed no concentrates averaged 5,883 lbs. milk and 342 lbs. fat a year.[65] They were provided with all-year pasture, crimson clover or crimson clover and ryegrass being used from late fall until spring. In addition they were fed alfalfa hay and silage, thus having an abundance of good roughage at all times. Though good production was thus secured without concentrates, other cows fed an average of 1,933 lbs. concentrates a year produced 980 lbs. more fat-corrected milk.

1029. Liberal feeding necessary for good production.—Good milk production cannot be secured unless cows have an abundance of feed. When concentrates are so high in price in comparison with roughage that it is wise to feed less concentrates than normal, special care must be taken to keep the cows filled up with high-quality roughage. Otherwise, production will be so low that the net returns will be seriously reduced.

The financial benefits from the proper feeding and care of good cows are shown in a striking manner by an Indiana demonstration.[66] Cows that were of good type, but which had been low producers, were selected from farms where the cattle had not been well fed. They were then brought to the Station and properly fed and cared for. On the Indiana farms these cows had produced an average of only 5,064 lbs. milk, but in the Station herd the following year they averaged 8,662 lbs. Though the annual feed cost per cow was 65 percent higher than when they had been fed poorly, the investment in proper feeding and good care brought 74 percent greater net return over feed cost. Just as striking proofs of the benefits from proper feeding and care are furnished by numerous instances in the records of cow-testing associations, where dairymen have greatly increased their net income by adopting improved methods.

1030. Feeding only a limited amount of roughage.—Some producers of market milk on high-priced land near the large cities follow the plan of limiting the amount of roughage and feeding an unusually liberal amount of concentrates. They do this because they wish to keep the maximum number of cows on their farms, and they can more readily provide additional feed in the form of purchased concentrates than in the form of purchased roughage. In other dairy districts, the supply of home-grown roughage may occasionally be seriously reduced because of drouth.

Under such conditions, the problem

always arises as to whether it is more economical to buy hay or to purchase additional concentrates as a substitute for part of the usual roughage allowance. The net energy values of concentrates and of hay provide the best basis for making a decision. Comparisons based on total digestible nutrients will give somewhat too high a value to hay, if there is already available on the farm enough good-quality roughage to supply sufficient bulk and enough vitamins.

[illegible] concentrate mixture [illegible] about 70 to 75 therms of [illegible] energy per 100 lbs., while good-quality hay will supply 40 to 45 therms per 100 lbs. On the average, it will take about 1.75 lbs. of good hay to provide as much net energy as is furnished by 1.0 lb. of a good dairy concentrate mixture. On this basis, such a concentrate mixture would be worth 1.75 times the price of good hay as a substitute for part of the roughage usually fed to dairy cows.

It is wise to feed cows at least half the normal amount of roughage, instead of replacing any larger proportion with concentrates. Good roughage is usually the chief source of carotene in winter rations. Also, a certain amount of good roughage seems to be necessary for ruminants to digest and utilize their feed normally. (45)

Several experiments have proved that if cows are fed only a small amount of hay and no other roughage, but with a liberal amount of a concentrate mixture, bad results follow.[67] The milk yield usually declines decidedly, the fat percentage falls greatly, and the cows frequently go "off feed." In some experiments the fat test has declined somewhat when as much as 8 lbs. of hay a day has been the only roughage. Finely-ground hay has a more pronounced effect than the same weight of long hay. This effect is very marked and the results may be serious if only 2 to 4 lbs. of hay are fed, with no other roughage. In Wisconsin trials the milk in some cases had less than 1 per cent fat.

Bulky concentrates, such as brewers' dried grains, dried beet pulp, or dried citrus pulp, were not a satisfactory substitute for all the roughage in Florida experiments.[68] A very marked decline in fat test has been reported in some instances when cows have been pastured on very young cereals, without other roughage.

1031. Including alfalfa hay in concentrate mixture.—If plenty of ordinary roughage is available on the farm, there is no advantage in adding ground alfalfa hay or alfalfa pellets to the concentrate mixture. The added alfalfa is still hay, and not a concentrate.

The experiments summarized previously show that milk production is not increased by this addition, and it is necessary to feed enough more of such a mixture to offset the lower amount of total digestible nutrients and net energy in hay. (459) When 20 or 30 per cent of alfalfa meal or pellets has been included in a concentrate mixture, the added alfalfa has been worth only about two-thirds as much as the usual concentrate mixture.

1032. Self-feeding cows.—Although the self-feeding method is widely used in swine feeding and is also often employed in the fattening of cattle and lambs, self-feeding a concentrate mixture is not satisfactory for dairy cows. Experiments at the Illinois and Virginia Stations show that when cows are self-fed grain and other concentrates they will eat a much greater amount than they need, thus making the method decidedly uneconomical.[69] If self-fed different concentrates, free-choice, they will also eat a much larger proportion than necessary of the protein-rich feeds.

A mixture of concentrates and coarsely ground or chopped hay can be self-fed to cows, the proportion of hay depending on the milk production.[70] However, the milk yields of the various cows in a herd differ widely, and those yielding a small amount of milk need much less concentrates than the cows producing at a high level. Self-feeding the same mixture of concentrates and hay to all the cows does not adjust the concentrate intake to the actual needs of the individual cows.

1033. Mineral requirements.—It has been shown in Chapter VI that in most regions common salt is the only mineral that is usually deficient in rations that are otherwise satisfactory for cattle.[71] Since milk is very rich in calcium and phosphorus, it may sometimes be necessary to feed dairy cows a supplement furnishing one or both of these minerals, as advised later. In the areas where there is a deficiency of one of the trace minerals, the lack should be corrected, as explained in Chapter VI.

1034. Salt.—Except in a very few areas where the forage has an unusual content of common salt, salt should be supplied regularly to cattle, as advised in Chapter VI, or they will not thrive. (**140**) Probably the best plan, in the case of cows being fed the usual amount of a concentrate or "grain" mixture, is to mix 1.0 lb. of salt with each 100 lbs. of concentrates, and then in addition provide salt in a salt box or by the use of salt blocks, so the cows can always have access to it. Mixing some salt with the grain mixture tends to make it more palatable and also insures that the cows get salt each day. Most of the formula dairy feeds contain added salt.

Extensive experiments on the salt needs of dairy cattle have been conducted recently by Smith and associates of Cornell University.[72] When no salt was supplied dairy cows, they soon showed marked craving for it. However, appetite, milk production, and live weight were not affected for 5 months or more. Then cows suffered greatly from the lack. The milk yield fell, the cows lost much weight, and death could occur. Recovery was rapid when salt was supplied.

The experiments showed that about 1 ounce per head daily met the requirement for cows producing up to 12,000 lbs. of milk a year. When cows were fed the usual amount of concentrates, this need was met nicely by including 1 per cent of salt in the concentrate mixture. When cows fed a concentrate mixture containing no salt were allowed free access either to block salt or to granular salt in a weather-protected box, they consumed about twice as much granular salts as of block salt. However, those getting block salt took enough to meet their needs.

1035. Phosphorus requirements.—Dairy cows usually receive sufficient phosphorus, if they are fed enough concentrates to meet the recommendations of the feeding standards and if the concentrate mixture contains at least 25 per cent of such high-phosphorus protein supplements as wheat [illegible] seed meal, or linseed meal. The [illegible] re- tion may be when the roughage [illegible] on soil decidedly lacking [illegible] the

A ration of roughage alone [illegible] only roughage and farm grain is apt to be deficient in phosphorus, especially for high-producing cows. Therefore a phosphorus supplement should be added to such rations, unless one is sure that the roughage has been grown on a soil well supplied with phosphorus and that it actually has a good phosphorus content. (**150**) Accordingly, a phosphorus supplement should usually be supplied to cows on pasture which are fed no concentrates, or when they are fed only cereal grain on pasture.

A phosphorus supplement is especially needed when a considerable part of the ration consists of a feed which is very low in phosphorus, such as beet pulp, molasses, cereal straw, or cottonseed hulls. The effects of a deficiency of phosphorus have been described in Chapter VI.

When there may possibly be a deficiency of phosphorus, it can readily be prevented by allowing the cows access to one of the mineral mixtures previously recommended, or else by adding 20 to 40 lbs. of bone meal or some other safe phosphorus supplement to each ton of concentrate mixture. (**186**) A phosphorus supplement containing a dangerous amount of fluorine should not be used. (**169**) If the concentrate mixture already has at least 0.5 per cent phosphorus, there is no need of adding a phosphorus supplement to it.

The amounts of phosphorus advised in the Morrison feeding standards (Appendix Table III) are based on the investigations of Huffman and associates

at the Michigan Station.[73] By computation, it will be found that the ration of a 1,200-lb. cow producing about 30 lbs. of milk a day should contain, on the air-dry basis, about 0.23 per cent phosphorus, and the ration of a cow yielding 60 lbs. of milk, about 0.26 per cent phosphorus. From the data in Appendix Table [illegible] one can determine the approximate percentage of phosphorus a particular ration will furnish, if the roughages have been grown on soil fairly well supplied with phosphorus. In computing the percentage of phosphorus in a ration containing silage, the silage should be reduced to an air-dry basis by dividing the weight fed by 3 and multiplying the phosphorus percentage shown in the [illegible] by 3. For example, 30 lbs. of well-matured corn silage of average composition, containing 0.07 per cent phosphorus, are approximately equal to 10 lbs. of air-dry silage containing 0.21 per cent phosphorus.

In West Virginia experiments Holstein heifers producing 20 to 30 lbs. of milk a day showed no serious evidences of phosphorus deficiency when receiving somewhat less phosphorus than recommended by the Michigan investigators.[74] However, it was believed that they were on the border line of deficiency, as they showed a lack of appetite and certain other symptoms.

1036. Calcium requirements.—In spite of the fact that milk contains a slightly greater quantity of calcium than of phosphorus, there is much less apt to be a lack of calcium in dairy rations than of phosphorus. This is because even non-legume roughages generally contain more calcium than phosphorus, and all legume roughages are very rich in calcium. Also, cows can apparently utilize the calcium in their feeds somewhat more efficiently than the phosphorus.

Dairy cows will receive plenty of calcium when at least one-quarter of their roughage, on the dry basis, is legume hay or other legume forage. Even when they receive little or no legume forage, the supply of calcium is not apt to be deficient if they are fed plenty of roughage of good quality, unless the forage is raised on soil very low in this mineral. When there is no legume roughage in the ration, it is probably wise to supply a calcium supplement as insurance against any possibility of deficiency, unless the non-legume roughage has been raised on soil well supplied with calcium. When such a phosphorus supplement as bone meal is fed, this will supply both phosphorus and calcium.

Calcium may readily be supplied by including 20 to 30 lbs. of ground limestone or other calcium supplement in each ton of the concentrate mixture, or by letting the cows have access to one of the mineral mixtures suggested in Chapter VI. (186) Unless the deficiency of calcium is serious, it is best to use not more than 20 lbs. per ton, or the palatability of the concentrate mixture may be lessened. Also, recent New Hampshire experiments have shown that the digestibility of protein may be decreased if too much calcium supplement is fed.[75]

In the Morrison feeding standards, the author has followed the recommendations of the special committee of the National Research Council concerning the amounts of calcium for dairy cattle.[25] It will be noted that 8 grams of calcium per day are recommended for the maintenance of a 1,000-lb. cow and 1 gram in addition for each pound of milk produced. An additional amount is advised for the last part of the pregnancy period. It will be found that most dairy rations which are satisfactory otherwise will provide more calcium than the minimums considered necessary.

Experiments have proved that good dairy cows are not injured when fed for long periods on rations having somewhat less calcium than advised in the standards. In Wisconsin experiments good cows were fed a concentrate mixture low in calcium, with timothy hay and corn silage for roughage in winter and with grass pasture in summer.[76] The winter rations had only about 0.20 per cent calcium on the dry basis. Other cows received a calcium-rich ration, with legume hay and pasture in place of the timothy hay and grass pasture, and with a mineral supplement furnishing addi-

tional calcium. The milk production was just as good on the low-calcium ration. Also, when some of the cows were slaughtered after 3 years on these rations, the skeletons of the cows fed the low-calcium rations were normal, containing as much calcium as those which had received the calcium-rich ration.

In Minnesota trials no serious results occurred when cows were fed for long periods on a ration having only 0.12 per cent calcium.[77] In order to reduce the calcium to this very low level it was necessary to feed only 6 to 7 lbs. a day of timothy hay that was unusually low in calcium. In similar experiments by the United States Department of Agriculture it was concluded that milk cows do not need more than 0.16 per cent calcium in the dry matter of the ration and that growing heifers require slightly less.[78]

Florida and Louisiana experiments show that where the soil is unusually deficient in calcium, dairy cows fed only non-legume roughage, even of good quality, may suffer seriously from a lack of the mineral, unless a calcium supplement is supplied.[79] In the Louisiana trials cows fed such a ration, very low in calcium but having adequate phosphorus, showed stiffness on walking, and in some cases humped back, bent hind legs, swollen leg joints, and constant licking. Some of the cows aborted, though the herd was free from brucellosis, and often the calves were born dead or very weak.

In the Florida experiments the cows, which had a liberal amount of concentrates, did not show the emaciation common in phosphorus deficiency. However, the milk yield was very low and some cows had suffered broken bones with no apparent cause. In both series of experiments the bad results were prevented when a calcium supplement was provided.

1037. Losses and storage of calcium and phosphorus.—Extensive experiments have shown the rather surprising fact that even when high-producing cows are fed ideal rations, rich in calcium and phosphorus, they frequently put more of these minerals into their milk at the height of milk production than they can assimilate from their feed.[80] During this period they therefore draw on the stores of these minerals in their skeletons. When they are producing less milk and especially when they are dry, they are able to rebuild their stores of calcium and phosphorus. It is therefore important to supply plenty of these minerals during the dry period.

To find whether the process of drawing on the mineral reserves during high milk production was injurious, continuous metabolism experiments over the entire lactation periods were conducted with good dairy cows by Ellenberger and associates at the Vermont Station and by Forbes and colleagues at the Pennsylvania Station.[81] The cows, which [illegible] 9,000 to 15,000 lbs. of milk a year, [illegible] calcium and phosphorus during the first part of the lactation period, when their yields were largest. However, in nearly all cases they stored sufficient of the minerals later so that by the next calving time the losses were more than replaced. This was true even when the cows were fed no legume hay, but only [illegible] timothy hay and corn silage as the roughages. Adding bone meal, ground limestone, or a mixture of the two tended to lessen the losses of minerals during the early part of the lactation period and to result in a greater storage for the entire year. There was, however, no proof that the addition of these supplements improved the health or production of the cows.

1038. Adding calcium or phosphorus to good rations.—Experiments have been conducted by several stations to determine whether or not there would be any benefit from adding a phosphorus and calcium supplement to good dairy rations.[82] In these experiments one group of cows has been fed a well-balanced ration, including plenty of good roughage and the usual amount of a concentrate mixture of the common type, with no mineral supplement except common salt. Another group has received the same ration, except that a mineral supplement, such as bone meal, has been added to supply additional phosphorus and calcium. In some cases a mineral mixture

has been used, containing such supplements as bone meal and limestone.

Unless the roughage was unusually low in phosphorus or in calcium, in most cases there has been no appreciable benefit from the use of these mineral supplements. This has been true even when little or no legume hay or other legume roughage has been fed. These experiments have definitely proved that the use of phosphorus or calcium supplements for milk cows is advisable only under the special conditions stated in the previous paragraphs.

1039. Trace minerals.—Except in the areas where there is a deficiency of one of the trace minerals—iodine, cobalt, copper, iron, or manganese—there is no benefit from feeding a trace mineral supplement, or in using trace-mineralized salt instead of common salt.[88] Detailed information on each of these minerals and on the way in which any deficiency can be corrected has been given in Chapter VI.

As stated there, the claims which have sometimes been made that manganese or other trace mineral supplements will prevent or cure brucellosis, have been proven false. (**180**) Studies have been conducted by the Wisconsin Station to determine whether a lack of trace minerals may be involved in repeat-breeding cows, which require repeated services to get them in calf.[84] It was concluded that trace minerals had little, if any, direct relationship to this problem.

Rations unusually low in manganese, having less than 4.5 milligrams per pound, produced normal growth of dairy heifers, but on this very low level of manganese they did not come into heat at as early an age as normal, and were slightly slower to conceive. Most ordinary dairy rations contain much more manganese than this.

1040. Vitamin requirements.—Under any usual conditions vitamin A and vitamin D are the only vitamins that need be considered in the feeding of dairy cows. (**198, 199**) Generally, there is no lack even of these vitamins when dairy cows are on pasture during the grazing season and are fed good roughage during the rest of the year, including a reasonable amount of satisfactory field-cured hay. The requirements of dairy cows for vitamin A and vitamin D are considered in detail in articles which follow. The vitamin requirements of dairy calves and heifers and also of dairy bulls are discussed in a later chapter.

The B-complex vitamins are synthesized by bacteria in the fermentations which normally occur in the rumen of cattle. (**209**) Except in the case of very young calves, ample amounts of these vitamins are therefore provided by the content in the feed plus the amounts synthesized by bacterial action. In Minnesota and New York experiments there was no advantage in adding yeast, which is rich in these vitamins, to a normal ration for dairy cows.[85] To ensure a plentiful supply of B-complex vitamins, brewers' dried yeast or some other B-complex supplement is often included in milk replacers for dairy calves weaned from milk at a very early age. (**1119**)

Sometimes when cattle are in a very run-down condition because of inadequate rations or because of disease or parasitic infection, the addition of yeast or B-complex vitamins may stimulate the appetite and be beneficial.[86] In such cases the normal bacterial action has probably not been taking place in the rumen.

Like other farm animals, dairy cows undoubtedly require ascorbic acid (vitamin C), but sufficient amounts are normally synthesized or formed in their body tissues. (**224**) When ascorbic acid is present in the feed of cattle, it is destroyed in the fermentations that take place in the rumen. Symptoms of scurvy, the disease caused by a deficiency of ascorbic acid, have been reported in dairy cows and calves in Michigan.[87] The condition of the cattle improved when they were treated by feeding chlorotone or by hypodermic injections of ascorbic acid.

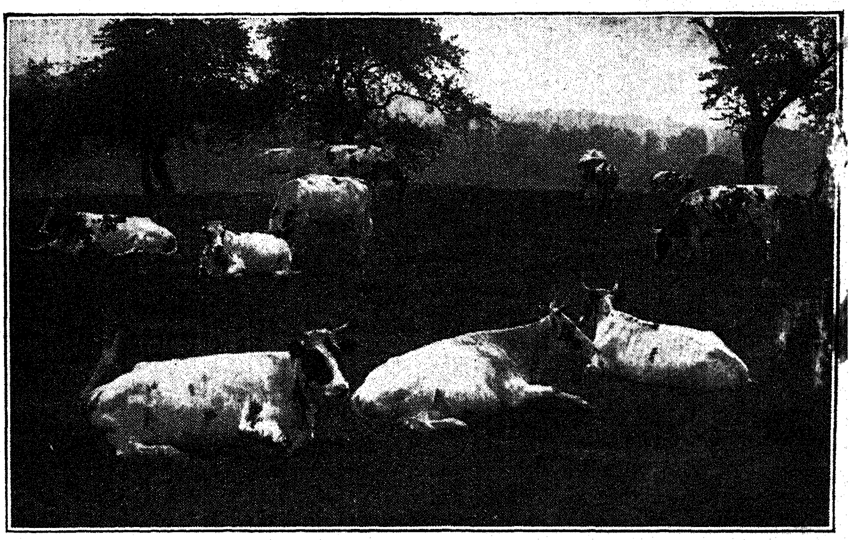
Advertising claims are made that the feeding of wheat germ oil or other vitamin E supplements aids in preventing or curing sterility in cattle. With reference to this matter, the author

agrees fully with the statement of a special committee of the National Research Council in their report on Recommended Nutrient Allowances for Dairy Cattle: "It appears that natural feed stuffs generally furnish adequate amounts of vitamin E to supply the small amount needed." [25]

Sometimes muscular degeneration, or dystrophy, and other symptoms occur in calves fed restricted rations, without a normal amount of milk or plenty of good roughage.[88] (223) Such trouble can generally be prevented by the use of a vitamin E supplement. In an Iowa experiment there was no benefit from adding a vitamin E supplement to a normal ration for dairy calves.[89]

1041. Vitamin A and carotene.— Dairy cows must have ample vitamin A to remain healthy and to produce thrifty calves, as has been shown in Chapter VII. Fortunately, plentiful amounts are furnished when cows have good pasture during the growing season and are fed a reasonable amount of good hay, with or without silage, during the barn-feeding period. These roughages supply liberal amounts of carotene, which animals readily convert into vitamin A in their bodies. Also, when animals are on good pasture, they store considerable vitamin A in their liver and other tissues. This helps to meet their needs whenever the supply in the feed may be scanty.

Only when special vitamin A supplements are fed, for instance in the case of young calves, do cattle normally secure any of their vitamin A needs from actual vitamin A in their feed, because all feeds of plant origin are believed to contain none. The vitamin A requirements are therefore commonly stated in terms of carotene.



CATTLE ON GOOD PASTURE STORE VITAMIN A

If dairy cows are on good pasture during the grazing season, they will start the barn-feeding period with a considerable store of vitamin A in their bodies.

In the Morrison feeding standards the carotene allowances provide 40 milligrams of carotene daily per 1,000 lbs. live weight for maintenance, and an additional amount of 30 milligrams daily for a 1,000-lb. cow during the last 2 to 3 months of pregnancy. These are the same amounts as recommended in the report by the special committee of the National Research Council, which has been referred to previously.[25] It is be-

lieved that these amounts are sufficient for normal yields of milk and satisfactory reproduction. As is shown later, the vitamin A value of the milk is increased considerably when the rations of cows provide far larger amounts of carotene or of vitamin A. (**1043**) The carotene and vitamin A requirements of calves are discussed in Chapter XXVII.

When dairy cows are fed a liberal amount of good-quality roughage, they will usually receive much more than the minimum amounts of carotene that have been mentioned. For example, 100 milligrams of carotene will generally be furnished by only 5 lbs. of field-cured legume hay of the best quality or by 14 lbs. of fairly good legume or mixed hay. The same amount of carotene will be provided by 20 lbs. of corn silage of average quality. (Appendix Table V.)

A fairly liberal supply of carotene is advisable for dairy cows during the latter part of pregnancy, because it increases the vitamin A store in the new-born calf and also increases the vitamin A value of the colostrum milk. (**270**) This tends to make the calves more vigorous and thrifty, and to lessen trouble from scours or other diseases.

The amounts of carotene needed by dairy cows for health and successful reproduction have differed somewhat in experiments to determine the minimum requirements.[90] Guernseys and Jerseys need more carotene per 1,000 lbs. live weight than do Holsteins, probably because they convert carotene into vitamin A less efficiently. It is believed that the amounts of carotene recommended in the standards are ample, even for these breeds.

It has been explained previously that feeding a large proportion of soybeans in the concentrate mixture for dairy cattle decreases the utilization of carotene or vitamin A. (**792, 798**) However, this is not of practical importance unless the ration is borderline in content of carotene or vitamin A.

1042. When may deficiencies of vitamin A occur?—It is important to know the conditions under which a deficiency of vitamin A may occur in the practical feeding of dairy cows. Fortunately, animals have a large capacity to store vitamin A in their bodies when the supply is very liberal. (**192**) If dairy cows are on good pasture during the grazing season, they may therefore have a sufficient store of vitamin A to enable them to get through the usual barn-feeding season without decided injury on a ration low in carotene. For example, in Oregon trials dairy cows which had been on excellent pasture in summer had normal calves in spring, even when fed poor-quality hay as the only source of carotene throughout the winter.[91]

However, it is not wise to feed rations low in carotene during all the winter, even when cows have been on pasture in summer. Unless they have a large store of vitamin A in the fall, it may be depleted within 2 to 3 months on a deficient ration.

That straw produces disastrous results when fed as the only roughage to dairy cows over long periods was shown in extensive Wisconsin experiments.[92] Cows fed wheat or oat straw as the sole roughage, with no pasture in summer, became unthrifty and aborted or had weak or blind calves. On the other hand, the results were satisfactory with well-cured corn fodder as the only roughage. The poor results were due to the deficiency of vitamin A and also to a lack of calcium. When these were added in later trials, reproduction was normal. It has been shown previously that the results were also disastrous in other experiments in which poor-quality timothy hay was fed for long periods as the only roughage. (**564**)

In Oklahoma trials prairie hay of good quality furnished ample carotene for dairy cows when it was fed liberally.[93] When only one-half the usual amount of hay was fed, with dried beet pulp replacing the rest of the hay, the supply of carotene was insufficient. In long-time New Mexico experiments a ration of whole hegari fodder (a grain sorghum) and cottonseed meal was so low in carotene that reproductive failure resulted and some of the cows died.[94] In North Carolina trials, including 26 per

cent of yellow corn in a carotene-poor ration of cottonseed hulls and cottonseed meal did not provide sufficient carotene.[95] Including 20 per cent of good soybean hay in the ration furnished enough carotene, but the same amount of poor-quality alfalfa hay was inadequate.

In general, it seems safe to conclude that if cows have reasonably good pasture in summer and if at least one-half their roughage during the barn-feeding season is good-quality hay or silage, there will be no deficiency of vitamin A.

1043. Effect of breed on vitamin A value of milk and butterfat.—Part of the vitamin A value of milk and butterfat is due to the nearly colorless vitamin A which the cow has formed from the yellow carotene in her feed. Part is due to carotene which she has transferred unchanged into her milk.

Guernseys and Jerseys do not convert into vitamin A so large a proportion of the carotene they assimilate as do cows of the other breeds. They therefore secrete more carotene and less vitamin A in their milk, and this makes it yellower in color. Likewise, their body fat and even skin secretions are colored yellow by carotene. Holsteins, Ayrshires, Brown Swiss, and Shorthorns convert most of the carotene into vitamin A, and therefore their milk and body fat have but little yellow color. If Guernseys or Jerseys are fed a ration low in carotene for a long time, their milk will also have little yellow color.

Experiments have shown that when cows of the various breeds are fed similar rations, there is no appreciable difference in the total vitamin A value of the yellow-colored butterfat from Guernseys or Jerseys and that of the much paler butterfat from cows of the other breeds.[96] As Guernsey and Jersey milk is normally considerably richer in fat than Holstein, Ayrshire, Brown Swiss, or Shorthorn milk, it will have a correspondingly higher total vitamin A value per quart, if the cows are fed similar rations.

1044. Effect of ration on vitamin A value of milk and butter.—Over any long period, the vitamin A value of milk and butterfat depends entirely on the amount provided in the feed. Temporarily, a cow can draw on her body store for some of it. If cows are continuously fed rations low in carotene, not only will they themselves be injured, but also their milk will be very low in vitamin A value. This is very important, both from the standpoint of human nutrition and in raising dairy calves.

Experiments have shown that to secure the maximum vitamin A value in milk, a much larger amount of carotene must be supplied in the feed than is necessary for the well-being of the cow herself. For example, in Indiana experiments 460 milligrams of carotene were needed in the ration to secure the maximum vitamin A value in the milk.[97] As shown previously, this is about 5 times as much as is needed for the well-being of the cows and for successful reproduction.

Under practical conditions milk has the maximum vitamin A value when the cows are on good pasture.[98] During the barn-feeding season the vitamin A value is less, but it may be kept reasonably high when good-quality hay and silage are fed. Since well-preserved hay-crop silage has more carotene than does corn or sorghum silage, it aids in maintaining a high vitamin A value and also yellower color in milk. (437) It has been shown previously that the feeding of soybeans or of soybean hay containing a considerable amount of soybeans decreases the vitamin A value of the milk. (792)

A very extensive study of the vitamin A value of butter and milk in various states has recently been made by the United States Department of Agriculture in cooperation with various experiment stations.[99] It was found that 4 per cent milk produced under winter-feeding conditions had an average vitamin A potency of 1,140 International Units per quart, and summer milk a potency of 1,800 International Units. However, much milk produced when cows are on first-class pasture has 2,000 to 3,000 Units per quart. The average potency throughout the year was 1,530 International Units. The average potency of

creamery butter was about 15,000 International Units per pound, with an average of approximately 18,000 Units for summer butter and 11,200 for winter butter.

When cows are fed adequate rations, only a small percentage of the vitamin A value of their feed is transferred into their milk. In various experiments the recovery of vitamin A value in the milk has not been more than 2 or 3 per cent of that in the feed.[100] If rations are fed that are very rich in carotene, the percentage recovery in the milk is much lower.

1045. Effect of adding a vitamin A supplement to good rations.—When dairy cows are fed plenty of good hay and silage, supplying still more vitamin A or carotene by the use of a special vitamin supplement will increase the vitamin A potency of the milk somewhat. However, it is doubtful whether it will generally increase the yield of milk or fat, or at least increase it enough to warrant the expense.

In Florida, Idaho, and Wisconsin experiments the yield of milk or fat was not increased by adding to good rations over 1,000,000 International Units of vitamin A per head daily in the form of shark-liver oil, which is exceedingly rich in the vitamin.[101] In fact, the shark-liver oil tended to reduce the yield in the Wisconsin trials. In certain other experiments the addition of shark-liver oil or other vitamin A supplements has slightly increased the milk yield.[102]

Cod-liver oil should not be used as a vitamin supplement for dairy cows, because it decidedly lowers the richness of the milk. (**207**)

1046. Vitamin D.—Although dairy cows require vitamin D, adequate amounts are generally supplied by sun-cured roughages or are provided by the action of sunlight. However, advertising claims are often made that dairy cows are greatly benefited by vitamin D supplements.

After considering all the data on the vitamin D requirements of dairy cows, the author agrees fully with the conclusions of the special committee of the National Research Council in their report on *Recommended Nutrient Allowances for Dairy Cattle.*[25] They state: "It is probable that under usual farm conditions adequate amounts of vitamin D are supplied by sun-cured roughages or provided by the action of sunlight."

Cows which are on pasture during the summer grazing season start the barn-feeding season with a considerable store of vitamin D in their bodies. This is due almost entirely to the anti-rachitic effect of the ultra violet rays in the sunlight, as green pasture forage has little or no vitamin D. (**204**)

In South Dakota experiments, in order to produce any symptoms of vitamin D deficiency in dairy cows, it was necessary to keep them entirely out of the sunlight and to feed abnormal rations, containing no field-cured hay or other sun-cured roughage.[103] Adding as little as 2 lbs. per head daily of good field-cured alfalfa hay to such rations cured cows showing severe vitamin D deficiencies, even though they were never exposed to sunlight.

Even when cows had no exposure to sunlight and were fed a ration devoid of vitamin D, with molasses beet pulp in place of hay, high-producing cows did not show definite symptoms of vitamin D deficiency until after about 4 months in the South Dakota experiments. Cows giving 25 to 40 lbs. of milk a day did not become depleted of their store of vitamin D until after 6 to 8 months.

In these experiments it was found that if cows suffering from a vitamin D deficiency produced by these abnormal conditions were continued on the deficient ration, but exposed to sunlight, they recovered rapidly. This was true even in the fall and winter, when sunlight has less anti-rachitic effect. For example, a cow showing severe symptoms of deficiency in late October was restored nearly to normal in 6 weeks when continued on the deficient ration but exposed to the late fall and early winter sunlight.

There is insufficient information as yet to warrant definite conclusions con-

cerning the minimum amounts of vitamin D required by dairy cows. Wallis found that a cow which had developed definite symptoms of vitamin D deficiency on the abnormal ration without sunlight, improved greatly when 3,000 International Units of vitamin D were added.[104] Even oat straw had 748 International Units of vitamin D per pound in the South Dakota studies. The feeding of 8 to 10 lbs. of most field-cured hay would supply 5,000 to 6,000 International Units of vitamin D. Barn-dried hay and wilted hay-crop silage have been found to supply enough vitamin D to protect calves against rickets. (**204**)

The vitamin D requirements of dairy calves are discussed in Chapter XXVIII. (**1118**) As stated there, under certain conditions, a vitamin D supplement should be added to the rations for dairy calves.

1047. Adding vitamin D supplements to ordinary rations.—In a Massachusetts experiment there was no benefit from adding irradiated yeast as a vitamin D supplement to the ration of dairy cows maintained under good practical conditions.[105] Similarly, in an Ohio trial under farm conditions, the exposure of dairy cows to the light from ultra-violet lamps, in addition to normal exposure to sunlight, was not beneficial to the cows, though it increased the vitamin D content of the milk.[106]

In a long-time Vermont experiment dairy cattle were fed for consecutive generations on good, early-cut timothy hay in comparison with late-cut timothy hay.[107] Both groups received silage and normal amounts of concentrates lacking vitamins A and D. The cattle were not pastured during the summer, but were turned out for a short time daily throughout the year for exercise. During the growing season they were fed a limited amount of green soiling crops. Some of the cattle fed each kind of hay received a vitamin A and D supplement (cod-liver oil concentrate).

Even though these cattle were exposed much less to sunlight than if they had been on pasture, no animals showed any deficiency of vitamin D, even on the poor-hay ration without any vitamin supplement. Also, there were no indications of a deficiency of vitamin A. The addition of the vitamin supplement was of no benefit to the cattle fed the good-quality timothy hay, and of only slight benefit to those fed the poor hay. Until the heifers were a year old, the good hay produced definitely better results than the poor hay.

In a New York trial, feeding a vitamin D supplement to dairy cows for 8 weeks before calving, increased the vitamin D content of the blood of the cows, but did not consistently change the store in the calves at birth.[108] The feeding to dairy cows susceptible to milk fever of extremely large doses of vitamin D as a preventive, for a very few days before calving, is discussed in the next chapter. (**1086**)

1048. Adding various mineral and vitamin supplements.—Claims are sometimes made that the addition of various mineral and vitamin supplements to good dairy rations will prevent or cure brucellosis (Bang's disease) and lessen other breeding troubles. An extensive experiment was conducted at the Wisconsin Station to find whether the ravages of Bang's disease could be lessened by rations which were ideal and contained an abundance of legume forage, with mineral and vitamin A and D supplements in addition.[109] Cattle raised on such a ration showed no more resistance to the disease than others which were fed ordinary rations that provided sufficient protein but that had no legume forage and no mineral or vitamin supplements. In other experiments trace mineral supplements have been ineffective as preventives of brucellosis. (**180**)

The effect of adding vitamin A or vitamin D supplements to good dairy rations has been discussed previously in this chapter, and the use of kelp and mixtures containing kelp has been considered in Chapter XXIII. (**977**) In most other experiments there has been no benefit from adding complex mineral and vitamin supplements to the ordinary types of good dairy rations.[110] Sprouted oats, sometimes recommended as a pre-

ventive of breeding difficulties, had no apparent beneficial effect in Nebraska tests with dairy cattle.[111]

1049. Water.—Often the production of cows is lessened because they cannot readily get plenty of water. There is no greater folly in dairying than this, for feed and labor are expensive in comparison with water. Of all farm animals, dairy cows in milk require the greatest amount of water in proportion to their size, because water forms about 87 per cent of the milk they yield.

The amount of water cows will drink depends on their size, the yield of milk, the air temperature and humidity, and the amount of water in the feed they eat.[112] From 100 lbs., or 12.5 gallons, up to 120 lbs., or 15 gallons, per head daily is an average amount for a herd, including both cows in milk and dry cows. Cows producing 100 lbs. of milk a day may drink 300 lbs. of water a day or even more.

Experiments have shown that providing water by means of automatic drinking bowls, so the cows can drink whenever they wish, increases the milk yield of good cows 3.5 to 4.0 per cent over watering twice daily, and 6 to 11 per cent over watering once daily.[113] It also saves labor and aids in providing a more sanitary supply of water. When drinking bowls are not used, high-producing cows should be watered at least twice a day, and in severe weather they should be watered indoors, if possible. There is less benefit from the use of drinking bowls for low producers than for high producers. Cows watered with water bowls drank an average of about 10 times each 24 hours, and about one-third of the water was drunk during the night, from 5 p.m. to 5 a.m.

It was found on 500 Maine farms that the milk yield of cows watered with drinking cups was 19 per cent greater than in herds watered out of doors and 9 per cent more than in herds watered from a tub in the barn.[114] The greater production secured with drinking cups was undoubtedly due partly to the facts that the owners were more progressive dairymen, had better cows, and fed and cared for them more efficiently in other respects.

When cows drink from an outdoor tank, it is probably wise to warm the water during very cold winter weather, so they will drink sufficient for their needs. However, in a Washington test the production was not increased by warming the water for one group of cows, in comparison with another group receiving water which had a temperature of about 32° F. most of the time.[115]

Care should be taken to keep drinking bowls and tanks in a sanitary condition by frequent cleaning. This is an important point that is often overlooked.

Including both the water in their feed and the water they drink, cows consume from 3.4 to 5.5 lbs. of water for each pound of milk they yield. On a ration of silage, hay, and concentrates, they will drink in ordinary weather 2.3 to 4.4 lbs. of water per pound of milk produced, in addition to the water in their feed.

In hot weather cows may drink 80 per cent more than in moderate weather. However, in a California test cows did not drink much more water at air temperatures up to 80° F. than at a lower temperature, when the air humidity and movement were kept constant.[116] In weather down to freezing temperature, cows drink about the same amounts as in moderate weather, if the water is not too cold and is comfortably accessible.

The feeding of a ration very high in protein considerably increases the water consumption. Adding any succulent feed to a dry ration decreases the water drunk, but not the total intake of water. If roots are fed in place of silage, cows drink less water, but the total water intake in feed and water drunk is greater on the root rations.

1050. Antibiotic feed supplements.—Iowa, Kansas, and Louisiana experiments have shown that there is no benefit from adding an antibiotic feed supplement to rations for dairy cows.[117] Neither the milk production nor the fat percentage has been increased. In Wisconsin tests feeding an antibiotic supple-

ment was not an aid in getting hard-to-settle cows in calf.[118]

When cows have been fed an antibiotic supplement no detectable amount has been found in the milk. On the other hand, when an antibiotic is introduced into a quarter of the udder to treat mastitis, the milk from that quarter should not be used for human consumption for 3 days, because of the presence of the antibiotic.

1051. **Thyroprotein.**—Many experiments have been conducted in this and other countries to determine the effects of adding thyroprotein, or iodinated casein, to the rations of dairy cows.[119] (**54**) These investigations have shown that when thyroprotein is fed under optimum conditions to good cows after they have passed the peak of milk production the milk production is generally increased from 10 to 25 per cent for a period of 4 to 10 weeks. The percentage of fat in the milk is also usually increased slightly. After the feeding of thyroprotein is discontinued, the milk yield is apt to fall below the normal amount, and consequently there may be little increase in milk production for the entire lactation.

The drop in yield can be lessened by gradually withdrawing thyroprotein from the ration, instead of discontinuing it abruptly.

When cows are fed thyroprotein, it is essential that a considerably greater amount of concentrates be fed than normal for the amount of milk produced. Otherwise, they lose much weight and run down badly in condition. To prevent great loss in weight it has been necessary to supply about one-fourth more total digestible nutrients in the ration than normally required. Because of this and also because of the lowered milk yield after thyroprotein feeding is discontinued, appreciably more feed may be required per 100 lbs. milk during the entire lactation when thyroprotein is thus fed.

Feed manufacturers making a formula dairy feed containing thyroprotein add enough of the product so that each pound of the mixed feed contains 5 grams of thyroprotein. They commonly recommend that 3 lbs. of this special feed be given per head daily, in addition to the usual concentrate allowance. Even this extra concentrate supply may not be sufficient to prevent some cows losing much weight, but they regain it when the supplement is discontinued.

It is not advisable to continue feeding thyroprotein during the greater part of the lactation period. In extensive experiments by the United States Department of Agriculture, when cows were fed thyroprotein for 200 to 300 days during successive lactations, the milk and fat production was decreased below normal in later lactations.[120] Also, the death loss of calves was much greater.

For the best results, thyroprotein should not be fed for more than 90 to 120 days, and not during the first 50 days of lactation or in the latter part.

Feeding the drug in hot weather increases the respiration rate so much that the cows may pant and even froth at the mouth. It should therefore not be used during hot summer months. The heart rate is also increased by the drug, but there is apparently no injury to the heart when the recommended amount is fed.

The use of thyroprotein is prohibited by the Purebred Cattle Association of the United States for cows which are on official test. In Great Britain its use in cattle feeds is authorized only for experimental purposes.

After reviewing the experimental data on thyroprotein feeding, the Committee on Animal Nutrition of the National Research Council concludes, "The available data suggest no definite economic advantage of feeding thyroprotein to dairy cows under most farm conditions." [121]

Its use may be advantageous in well-fed commercial herds during periods of short milk supply. Also, in a milk-marketing area where milk is priced on the base-surplus plan, feeding thyroprotein during the base period can raise a dairyman's base quota of milk, and thus increase the price he receives for milk produced during the months of abundant supply.

The limited data available indicate that it is not beneficial to feed thyroprotein to dairy calves.[122]

1052. Preparation of feed.—The various grains should be ground or crushed for dairy cows and heifers, since a considerable percentage otherwise escapes chewing and digestion. The only exception is when grain is unusually cheap, compared with the cost of grinding. Most grain need not be ground for calves up to 6 to 9 months of age.

Medium-fine grinding of grain is decidedly preferable to a floury, dusty meal. It not only takes much less power and time, but also grain ground only medium fine is more palatable and actually has a higher feeding value.[123] (**89**)

Some dairymen prefer a coarse-textured concentrate mixture, or grain mixture, over the usual mixture of ground grains and other concentrates, and will pay a higher price for such a dairy feed. Coarse-textured formula feeds are made by including in them rolled or crimped grain instead of ground grain, pea size oil meals, and sometimes pelleted or crumbled feeds.

New Hampshire and New York experiments have shown that coarse-textured or pelleted dairy feeds have no advantage over the ordinary type of concentrate mixture.[124] In the New Hampshire tests an ordinary fine concentrate mixture was significantly higher in digestible protein and in total digestible nutrients, than a mixture of the same feeds fed in coarse-textured or pelleted form.

Michigan tests show that cows consume their allowance of concentrate mixture more rapidly when water is added to wet it thoroughly.[125] This may be an advantage when cows are fed the concentrate mixture in a milking parlor, and have but little time to eat it.

When cows are fed the usual amounts of concentrates, it does not pay to go to extra expense to chop or grind hay of such quality that it will be cleaned up reasonably well when fed uncut. Such preparation produces little or no increase in the digestibility of the hay. Fine grinding may even lower the digestibility and may cause a decrease in fat content of the milk.[126] (**1030**)

In numerous experiments cows fed chopped or ground hay in ordinary rations have produced no more milk or only slightly more than on uncut hay of good quality.[127] In no case has there been sufficient saving through chopping or grinding such hay to justify the added expense. If cows are fed only alfalfa hay, without any concentrates, it may pay to chop the hay, as they will then eat more hay.[128]

In the case of hay that is unpalatable or coarse and stemmy, there may be enough saving through chopping to warrant the expense, if it can be done cheaply. (**486**) However, it is probably a better plan to feed coarse, stemmy hay liberally, so the cows can pick it over and leave the coarsest stems, which have little feeding value. The refuse can be used for bedding or for feeding stocker cattle or idle horses that are being carried through the winter. Forcing cows to eat the stems of such hay by chopping or grinding does not convert the stems into good roughage. Chopping or shredding corn or sorghum fodder or stover is advisable to lessen the waste, and to facilitate handling the manure.

Where it seems desirable to prepare hay for dairy cows, chopping it by means of a silage cutter or other chopping machine is preferable to grinding it. Ground hay is often disagreeably dusty and may be unpalatable to the cows. Also, it has been found that if cows are fed finely-ground hay as the only roughage, the fat content of the milk may be decreased considerably, especially if they are fed only a small amount of hay.[129] This effect seems to be due to an interference with the normal fermentation processes in the rumen, which are essential for the digestion of roughages.

There is no advantage in mixing the concentrates with chopped or ground hay for dairy cows, although this has sometimes been advocated.[130] Likewise, there is no benefit from soaking or cooking ordinary feeds. In the case of a cow on official test, the concentrate mixture is

sometimes moistened before feeding, in order to induce her to eat a greater quantity than she might take otherwise. Also, dried beet pulp is sometimes soaked and fed as a substitute for corn silage. (943) Fermenting, or "pre-digesting," chopped or ground hay or mixtures of such hay and concentrates does not increase the value and is a waste of time and money. (94)

III. Factors Influencing the Composition and Yield of Milk

1053. Composition of milk.—The milk of the purebred or high-grade cows of any dairy breed has certain general characteristics, particularly in fat content and in color, although the milk of various individuals may differ considerably from the breed average in percentage of fat and total solids. While the fat content of cow's milk may range from less than 3 per cent to 6 per cent or over, there is much less range in the other constituents. The average composition of milk from purebred cows of the different breeds is shown in the following table: [131]

Composition of milk of purebred cows of various breeds

	Total solids	Fat	Protein	Lactose	Mineral matter
	Per cent	Per cent	Per cent	Per cent	Per cent
Ayrshire . . .	13.05	4.05	3.51	4.81	0.68
Brown Swiss	13.13	3.97	3.52	4.90	0.74
Guernsey . .	14.51	4.90	3.90	4.97	0.74
Holstein-Friesian .	12.32	3.45	3.30	4.89	0.68
Jersey	14.86	5.37	3.79	5.00	0.70
Shorthorn . .	12.57	3.63	3.32	4.89	0.73

Jersey and Guernsey milk is the richest in fat, and that of Holsteins the lowest in fat among the common dairy breeds in this country. However, the breeds which give milk high in fat usually yield a correspondingly smaller quantity of milk.

Apparently, the percentage of fat in the milk of purebred Holsteins has been increased appreciably during recent years in the herds of progressive breeders. In 1940 the average fat test of Holstein herds completing records in the Herd Improvement Registry was 3.46 per cent, while in 1954 the average for 2,037 herds and 53,580 cows was 3.67 per cent.[132]

As the fat content of milk increases, the percentage of protein rises less rapidly, and the percentages of calcium and phosphorus increase but slightly.[133] Milk contains about 3.0 per cent or more of casein, the chief protein. Normal milk also has approximately 0.50 per cent of milk albumin, 0.05 per cent of globulin, and traces of other nitrogenous compounds.

The chief difference in the total protein content of milk of various fat percentages is due to a greater or smaller percentage of casein, as the content of albumin and globulin does not differ much. Colostrum, the milk produced the first few days after calving, is very high in globulin, sometimes containing 10 per cent or more. (270)

The casein content of milk is of great importance in cheese making, since the yield of cheese depends not only upon the percentage of fat but also upon the percentage of casein. A milk testing 6 per cent of fat will not make twice as much cheese as one testing 3 per cent. Therefore, at cheese factories where the milk from different herds differs considerably in fat content, it should be paid for by some method which gives credit for both fat and casein.

The hardness of the curd from the milk of various cows differs widely, the curd tending to be harder as the casein content increases. Since soft curd milk is more readily digested than hard curd milk by infants and invalids, special methods are sometimes used to produce soft curd milk for such use. Homogenization makes the curd softer, and other processes have an even more marked effect.

It is well known that the fat in milk is in the form of minute globules or droplets, which are distributed throughout the milk in the form of an emulsion. The fat globules range in size from less than 1 micron to 10 microns or even more in diameter. (A micron is one-

thousandth of a millimeter or about 4 one-hundred-thousandths of an inch.) The minute size of the fat globules is shown by the fact that a quart of normal milk contains 4.5 to 9.0 trillion fat globules.

The fat globules of Jersey and Guernsey milk are larger than those in Holstein and Ayrshire milk, while the globules in Shorthorn milk are of medium size. Regardless of breed, there is a tendency for the fat globules to be larger at the beginning than at the end of lactation.

Practically all the sugar in milk is lactose, but it also contains a trace of glucose.[134]

1054. Factors affecting yield and composition of milk.—In addition to the influence of breed on the composition of milk, the yield and composition are affected by various other factors that have been discussed previously. (305–308) The amount of milk a cow produces is affected much more readily and to a greater degree than is its composition. The chief factors affecting the yearly yield of milk by any cow are her inherited productive ability, her thrift, her age, and the manner in which she is fed and cared for. The daily yield usually reaches a maximum the second month after calving and then decreases gradually as lactation progresses. Such factors as pregnancy, temperature, and turning to pasture may have an appreciable effect on the milk yield.

The fat percentage of milk varies much more than the content of protein, lactose, or minerals. While the average percentage of fat in the milk of an individual cow does not usually change much from year to year, the fat content may vary greatly from one milking to another, and often without any apparent cause. In general, whenever the yield of milk rises or falls considerably, the fat percentage is apt to change in the opposite direction.

The variations in fat content from milking to milking, and from day to day, are much greater than generally realized. In milkings made at the same time on successive days, variations of 0.5 per cent in fat are common and of 1.0 per cent not unusual. The variations in the percentages of fat in successive milkings are often greater than this, as the time of day may have an influence on the fat content of the milk.

Because of the variations in the fat percentage, testing the milk from only one milking is often a poor indication of the richness of the milk a cow is producing. Also, on account of the variations in composition of milk, a dairyman who is retailing milk should be sure to mix the milk from various cows thoroughly before bottling it. Otherwise, some of the milk may fall below the legal standards for fat or solids-not-fat, even though the average composition is satisfactory.

The fat content of milk is affected somewhat by the stage of lactation, tending to increase gradually after the second month. It is also affected by temperature and season of the year, by interval of time between milkings, by age, and by certain other factors. It may sometimes be increased temporarily by adding to the ration certain fat-rich feeds or fats, but the kind of feed does not ordinarily exert any large continued effect upon the fat percentage over a long period of time. Cows calving in fat condition may yield milk abnormally high in fat for some weeks after calving. The character of the fat may be greatly changed by the particular feeds in the ration.

The effects of the ration upon the vitamin content and the mineral content of milk have been discussed in earlier chapters. (307, 308, 1044) From the standpoint of human nutrition an exceedingly important fact is that the vitamin A value of milk depends on the amount of carotene in the ration. Milk from cows fed rations rich in carotene is high in vitamin value, while that produced on carotene-poor rations has a low content. This difference in vitamin A value is also of great importance in raising calves. (1117)

Various factors which affect the yield and composition of milk are discussed in greater detail in the following articles.

1055. Effect of age.—The annual yields of both milk and fat by a cow normally in-

crease from her first lactation until she is mature. This is primarily because of the increase in her size. (1004) The maximum yield is usually reached at 6 to 7 years of age, but the increase is only slight after 5 years.[135] The various dairy breeds differ somewhat in the age at which they reach mature size. Brown Swiss and Milking Shorthorns mature more slowly than Holsteins or Ayshires, and Jerseys and Guernseys mature earliest.

Most cows are removed from the herd because of udder trouble, failure to breed, or other causes before their yield is much reduced by old age. Usually there is no marked decline in yield until 12 years of age, if the cow is in good health.

To compare the production of heifers with that of mature cows, the records are converted to a "mature-equivalent basis" by multiplying the actual yield by an "age-correction factor." Based on extensive studies, Kendrick of the United States Department of Agriculture has prepared tables which state the factors to be used for converting 305-day production records of cows calving at different ages to the mature equivalent basis.[136] For example, the following factors are used for Holsteins: For a heifer calving at 2 years of age, 1.31; for a cow calving at 3 years of age, 1.18; at 4 years, 1.08; and at 5 years, 1.02.

The records of cows calving at older ages than 7 or 8 years are similarly multiplied by factors to convert them to the "mature-equivalent basis."

The fat percentage is affected but little by age, though there is usually a very slight tendency for it to decrease as a cow grows older.[137] In culling cows it is important to bear in mind that while a heifer will ordinarily increase in milk yield with age, the richness of her milk will tend to decrease.

Cows are usually more persistent producers in their first lactation than in later lactations. In other words, the production decreases less rapidly from month to month. This is probably because a heifer is growing in body, and the amount of secreting glandular tissue in her udder is also increasing.

1056. First and last drawn milk; thorough milking.—The milk drawn first from the udder at a milking is usually very poor in fat, and each successive portion increases in richness. While the first portion may have less than 1 per cent fat, the strippings from the same cow may contain 6 to 10 per cent.

There have been several theories concerning the cause of this difference in fat content.[138] The most probable explanation seems to be that the fat globules tend to be retained in the secretory cells of the alveoli, and the other milk constituents pass out first. Then, as the pressure in the udder is released by milking, the fat globules pass out. It was formerly believed that the difference was due to a tendency of the fat to rise in the milk that is contained, previous to milking, in the milk cistern and large ducts of the udder.

If the udder is massaged before milking starts or if the cow has just had considerable exercise, the difference is much less than if she has been standing quietly in the stable. It also tends to be less in low-producing cows than in high producers. Since the strippings are so much richer in fat, the yield of fat and the richness of the milk are appreciably decreased when cows are not milked thoroughly. The percentages of other constituents than fat vary but little in the successive portions of milk drawn from the udder.

Foremilking, or discarding the first few streams of milk from each quarter of the udder, is sometimes done to increase the fat content of market milk. The discarded milk is then used for feeding calves or other stock. However, New York tests show that a considerable part of the milk must be discarded to make any very marked increase in the richness of the remaining milk.[139] Discarding the first 20 streams from each quarter increased the fat content of the rest of the milk only 0.17 per cent. Yet, to obtain this increase nearly 10.5 per cent of the entire milking was discarded.

To secure an accurate index of a cow's production on an official test, it is important that she be milked clean at the milking before the test period starts. Incomplete milking previously will tend to slightly increase the yield of milk, the percentage of fat, and the yield of fat during the test period.[140]

The importance of proper milking and the way in which cows "let down" or "hold up" their milk are discussed in the next chapter. (1093)

1057. Length of period between milkings; night and day.—When the intervals of time between milkings are unequal, cows generally yield a smaller amount of milk after the shorter period, but this milk is usually slightly richer in fat and total solids.[141] With cows milked twice a day, a difference of 4 hours in the two periods may make a difference of 0.5 to 1.0 per cent in fat content.

If cows are milked twice a day with

equal intervals between milkings, the evening milking tends to be slightly richer in fat than the morning milking. This may be due to the effect of the exercise during the day. When cows are milked three or four times a day, the milkings during the middle of the day tend to be slightly higher in fat.

When cows are milked twice a day, it is often desirable because of labor convenience to have a shorter interval between the morning and night milkings than between the night and morning milkings. In a Minnesota experiment with identical twins, the productions of milk and fat were just as high when the cows were milked at 10 and 14 hour intervals as when the intervals were equal.[142]

1058. Frequency of milking.—Milking cows of ordinary productive capacity more than twice a day does not markedly increase their production, and is generally not economical. However, if cows capable of higher production are milked more than twice a day and are fed concentrates according to production, the milk yield will usually be increased considerably.[143] This is because the rate of milk secretion decreases as the pressure within the udder grows greater when it becomes filled with milk. (296) Whether or not it will pay to milk good cows more than twice a day will depend upon the price received for the milk, in comparison with the cost of labor.

Milking cows of high productive capacity more than twice daily tends to increase their persistence in production throughout the lactation and may increase the fat test slightly. The increase in yield by milking 3 or 4 times a day will be greater for heifers than for older cows.

From extensive studies of the available data, Kendrick of the United States Department of Agriculture has estimated that when cows are milked 3 times a day throughout the lactation the average increase in yield over twice-a-day milking, with the more liberal feeding that generally accompanies it, will be about 20.5 per cent for heifers 2 to 3 years old at calving, 17.6 per cent for cows 3 to 4 years old at calving, and 14.9 per cent for those 4 years old or older.[136] The increase in yield over twice-a-day milking from milking 4 times a day will average 35.1, 29.9, and 26.6 per cent for cows calving at these ages.

To convert records of milk production of cows milked 3 or 4 times a day to the basis of twice a day milking, factors are used which depend on the number of days a cow has been milked more than twice a day.[136] For example, if a heifer calving at 2 to 3 years of age has been milked 3 times a day during a 305-day lactation, her actual milk yield is first equated to the mature-equivalent basis and then multiplied by the factor 0.83. If she had been milked 4 times a day during the entire lactation period, the factor 0.74 would be used.

1059. Effect of advancing lactation and of pregnancy.—After calving, the milk yield of cows usually increases until it reaches a maximum during the second month of lactation. It then gradually decreases as lactation advances, the average monthly decrease in well-bred herds being about 6 or 7 per cent from the second to the seventh month.[144] The monthly rate of decrease varies considerably in individual cows, ranging from only 4 per cent or less to 9 per cent or more, depending on their persistency of production. After the seventh month, the rate of decrease is considerably more rapid in cows bred to calve with the usual frequency. Cows of the dual-purpose breeds are usually less persistent milkers than cows of the special dairy breeds, and their monthly rate of decline is more rapid.

Pregnancy does not materially affect the milk yield until after about 5 months, after which it considerably hastens the decline.[145] For this reason, separate classifications are provided in the advanced registries of the dairy breeds for cows which meet definite calving requirements.

In the case of cows which are in good flesh at calving time, the fat percentage is apt to decline slightly for the first month or two after calving. This decrease is most marked in the case of Holsteins and Ayrshires. After the second or third month the fat content usually increases slightly, especially toward the end of lactation. Under usual farm conditions there is no marked change in richness until toward the end of lactation, when the fat percentage increases as the milk yield declines rapidly. In New Zealand studies advance in lactation did not affect the size of the fat globules.[146]

1060. Weather and season of the year.—The temperature of the air has an even more marked effect than the stage of lactation upon the fat percentage in milk.[147] Cows of all breeds tend to give milk lower in fat as the temperature rises, at least between the range from 30° to 70° or 80° F. The fat content may fall as much as 0.2 to 0.3 per cent for each 10° F. increase in temperature. The solids-not-fat percentage of milk also declines as the weather becomes

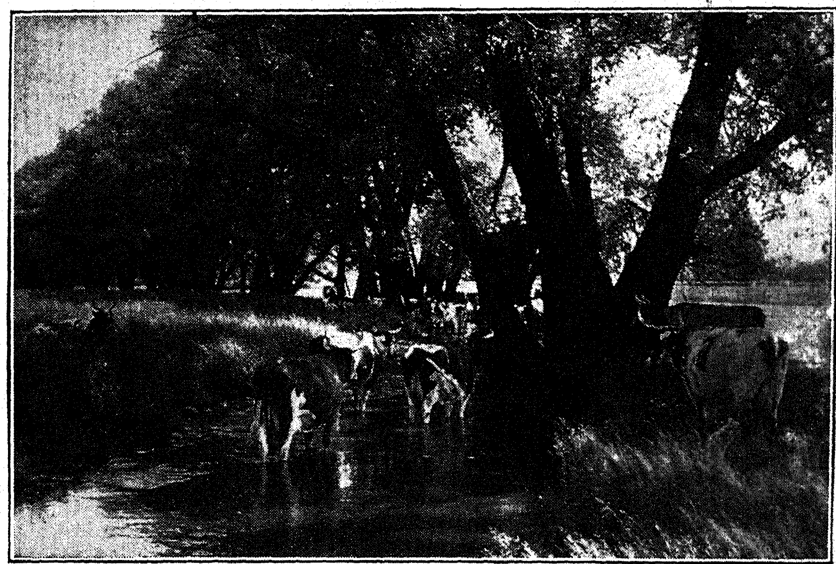
hot, and it may even fall below the common legal standard of 8.5 per cent. Because of the effect of temperature, cows at the same stage of lactation tend to give richer milk in winter than in summer. In hot climates the average fat content and the solids-not-fat tend to be lower than in cooler regions.

Very hot weather has a marked effect upon cattle of our ordinary breeds, as has been pointed out in Chapter VIII. (233) This is because they cannot sweat appreciably and they do not have any efficient means of ridding their bodies of surplus heat. Their body temperatures therefore rise decidedly and their respiration rates become much more rapid, because they pant in an effort to get rid of the surplus heat.

If the weather is extremely hot, it may cause a marked reduction in milk yield, and the fat content may then be increased and the composition of the milk otherwise changed. This effect is most pronounced when the period of hot weather is prolonged. Often the decline in production of cows in hot weather in midsummer is caused to a much greater extent by a shortage of feed on scanty pasture, than by the heat.

In a California test cows kept in a green pasture field in very hot weather were much more comfortable than when confined to a bare corral, and their body temperature was appreciably lowered.[148] This was because the air immediately above the green forage was about 10° F. cooler than in the corral, because of the cooling effect produced by the evaporation of water from the growing plants. This shows the importance of pastures for cows in hot weather.

Shade should be provided on pastures in hot weather, if possible. In a Louisiana test the body temperature of cows kept in the sun in hot weather was 0.7° F. higher than when they were allowed access to shade.[149]



COMFORT OF COWS AFFECTS MILK YIELD

Shade in hot weather and access to a stream or pool in which the cows can wade increase their comfort. (From New York State College of Agriculture, Cornell University.)

Where cows have access to a stream or pool in which they can wade, it increases their comfort in hot weather. Cooling cows during periods of very hot weather by covering them with light muslin cloths kept moist to cause cooling by evaporation, overcame the depressing effect of the heat in a Georgia test, with no bad effect on health.[150]

When the weather is very hot, cows graze more at night than in the daytime. It is therefore important to have them on good pasture at night. Also, the forage on the daytime pasture should be plentiful, so the cows can get their fill before they stop grazing because of the heat.[151]

Exposure to cold rains or other severe

weather may cause a serious shrinkage in milk yield and a drop in fat content.

The effects upon cows of various stable temperatures are discussed further in the next chapter. (1088)

1061. Season of freshening.—Under the climatic conditions in the chief dairy districts of the United States, cows that freshen in fall or early winter, if properly fed and cared for, yield more milk and fat than those that calve in spring or summer. Fall-fresh cows give a large flow of milk in winter and then flush again with the stimulus of pasture in spring. The difference in average annual yield of cows freshening in fall and early winter and of those calving in spring or summer has usually ranged from 11 per cent or more to only 2.5 per cent.[152] In a region with a rather uniformly mild climate, as Western Oregon, the season at which a cow freshens may have no appreciable effect on yearly production.

The relative profitableness of "winter dairying" and "summer dairying" will depend on the prices received for milk at various seasons of the year and the relative cost of concentrates compared with pasture. (1100) When cows freshen in the fall, more of the work of milking comes in the winter when farm work is slack. More time can be given to raising the calves, and fall-dropped calves are large enough by spring to make good use of pasture and are better able to stand the hot weather. Also, under this system, on farms where the milk is separated on the farm, a larger supply of skimmilk is available for pigs or poultry in winter when it has the greatest value for them.

1062. Condition of flesh at calving.—It is well known that the milk yield of a cow is greater when she is in thrifty, vigorous condition at time of calving. The fat content of the milk is not usually affected greatly by the condition of flesh at calving, except in the case of cows which are so fed that they are really fat at calving.

When a cow of high productive capacity calves in a fat condition, her milk for a time may be considerably richer than normal in fat.[153] This is because her strong dairy temperament causes her to withdraw fat from her body and put it into her milk. During this time she will lose markedly in body weight. In the case of Holstein-Friesian cows the increase in fat percentage may be as great as 1 to 2 per cent. Any increase in the case of Guernseys and Jerseys is usually much less marked, and often there is none at all.

It is evident that when a cow calves in fat condition, a short-time record of fat production secured shortly after calving may not be a reliable index to her yearly fat yield. For this reason, brief official advanced registry tests are no longer sponsored by any of the dairy breed associations in this country.

The total yearly yield of fat can be increased by having cows calve in fat condition, and breeders running cows on advanced registry test usually take advantage of this fact.

1063. Influence of underfeeding and overfeeding.—If good dairy cows are underfed in the first part of the lactation period, they will sometimes maintain their milk flow at a nearly constant level for a short time under the most adverse conditions, drawing on their bodies for nutrients and losing in weight rapidly.[154] During this time the percentage of fat in the milk may be temporarily increased, if the cows were in good condition when the underfeeding started.[155] Underfeeding may also produce marked effects on the character of the butterfat. Later in the lactation period, even moderate underfeeding causes a large decline in milk flow, and it is then difficult to bring it back to normal by later liberality of feeding.

When cows are greatly underfed for considerable periods, the percentage of solids-not-fat may be decidedly reduced, and especially the percentage of protein.[156] Scanty feeding within reasonable limits does not apparently have any effect on the flavor of milk.[157] Starvation for a few days greatly decreases the yield of milk and may change its composition considerably.[158]

The most pronounced effect of overfeeding (feeding a more liberal ration than required) is to cause a cow to gain in weight, provided that the overfeeding does not cause her to go off feed.[159] Even when fed very liberally, a cow is unable to increase her milk flow beyond the fixed maximum she has inherited.

1064. Influence of feed on composition of milk.—If a cow receives enough nutrients to maintain her body weight and if her ration contains at least a certain minimum amount of fat, the richness of her milk cannot be increased very markedly over a long time by greater or less liberality of feeding or by supplying any particular kind of feed. Decided changes in the ration may, however, sometimes cause a marked temporary change in the fat content.[160] This effect usually lasts only a few days, and sometimes

there is no increase in the percentage of fat, or even a decrease.

A temporary increase in the fat content of milk is especially apt to result from adding to the ration a considerable amount of certain feeds high in fat, such as flaxseed, soybeans, cottonseed, or peanuts, or from feeding 1 lb. or more per head daily of certain fats or oils, such as butterfat, lard, tallow, coconut oil, linseed oil, cottonseed oil, or corn oil. Linseed meal, cottonseed meal, or soybean oil meal are less apt to produce such an increase, probably because most of the fat has been removed. Feeding a considerable amount of whole milk to cows that will take it also usually increases both the yield of milk and the fat percentage temporarily.

Coconut meal and palm-kernel meal in some tests have apparently caused a very slight increase in fat content for a considerable period, but in other cases the richness of the milk has not been increased.[161] In a New York experiment a trifling increase in the richness of milk was produced by substituting 10 per cent of coconut oil meal and 10 per cent of palm-kernel oil meal for equal amounts of more common feeds in the concentrate mixture.[162] The increase in fat percentage over 5-week periods was only 0.08 per cent, and was thus too small to be of practical importance. It has been previously shown that concentrate mixtures containing 25 per cent or more of soybeans tend to increase the richness of the milk, but they decrease its vitamin A content. (798)

In Ohio experiments in which rations very rich in protein were compared with rations extremely poor in protein, there was no appreciable change in the composition of the milk, except a slight increase in non-protein nitrogen on the ration very high in protein.[163]

Cod-liver oil and also menhaden fish oil cause a decided decrease in the fat content of milk when cows are fed 4 to 5 ounces per head daily.[164] Salmon oil or shark liver oil does not have any marked effect, nor does hydrogenated cod-liver oil.

The principal mineral constituents of milk are not changed to any appreciable extent by the amounts of minerals in the ration. (307)

1065. Changes in the character of fat.—While the feed does not usually change the percentage of fat in the milk much, in some cases the nature of the fat is decidedly altered by the feed, and this may noticeably affect the hardness of butter.[165] Butterfat is made up of several different kinds of fats. Some of these, such as stearin and palmitin, are solid at ordinary temperatures, while others, as olein and butyrin, are liquid. If cows are fed a considerable amount of a feed rich in fat, some of this food fat may pass without great change into the milk, thus altering the fat in a manner similar to the effect on pork when hogs are fattened on certain feeds. (276)

Feeds rich in vegetable oils (which contain a large amount of olein) generally produce butterfat high in olein. This usually tends to make the butter softer, but in some instances this tendency is offset by still other changes in the composition of the fat.

For instance, though the feeding of cottonseed meal, cottonseed, or cottonseed oil increases the amount of olein in the butterfat, yet it raises the melting point and makes the butter harder. This is probably due to a decrease in the amount of volatile fatty acids, which more than counterbalances the effect of the increase in olein. This effect of the heavy feeding of cottonseed meal or cottonseed on butter is of much practical importance in the southern states, for it is a cause of hard, gummy butter. Coconut oil meal or barley increases the hardness of butter, while corn and oats have a slight effect in the other direction.

The feeding of cows exclusively on alfalfa hay may cause sticky or crumbly butter, which condition can be remedied by adding corn silage to the ration, and also by special processes in manufacture.[166] Soybeans and rice polish make the butter soft, if they form too large a part of the concentrate mixture. Pasture generally produces milk fat higher in olein and hence causes softer butter. Jerseys seem to produce harder butter than Holsteins or Ayrshires when fed the same rations.

1066. Miscellaneous factors.—*Moderate exercise* tends to increase slightly the percentage of fat in milk and also the yield of fat.[167] For this reason and also to provide fresh air and sunshine, it is a sound plan in winter to turn cows out for exercise a part of each day when the weather is suitable. Too much exercise, or hard work, such as milk cows are often used for in some countries, lowers the yield and may decrease the fat content.

Turning cows to pasture from winter stabling usually increases both the yield of milk and its richness, but after 2 to 4 weeks the percentage of fat falls to normal.[168] The temporary increase in richness is probably due to the fact that early spring pasture is so watery that the cows do not get enough

nutrients and are therefore forced to draw on their bodies, losing weight meanwhile. Such underfeeding usually increases the richness of milk temporarily, if the cows are in a good state of nutrition when it starts.

Abortion causes a decidedly lower yield of milk than normal, the reduction being especially great if it occurs a considerable time before the time for normal calving. The eradication of brucellosis, or Bang's disease, from a herd greatly increases the milk yield and therefore causes a considerably greater net return.[169]

The *period of heat*, or estrus, contrary to popular opinion, does not generally have any marked effect on the yield of milk or fat. Cows have been found, on the average, to give 0.6 lb. to 1.5 lbs. less milk on the day of the most evident heat, but some cows showed no decrease at all.[170] A few nervous cows are affected more markedly.

Grooming cows is, of course, necessary in the production of high-quality milk with a low bacterial content, but it may not increase the yield of milk.[171] Grooming cows with a vacuum-cleaner type of grooming machine causes little or no increase in yield over hand grooming.[172]

Dehorning cows causes a small temporary decrease in milk flow, but it is repaid a hundred-fold in commercial dairy herds in the greater comfort of the cows thereafter and the lessening of injuries. From the standpoint of dairy efficiency, it is unfortunate that in the case of certain breeds, animals without horns are discriminated against in the show ring.

The *tuberculin testing* of cows has practically no effect on the yield of milk or fat.

Infestation with ticks may cause a serious decrease in yield, even when cows are immune to tick fever.[173] Therefore the eradication of ticks is very important in tick-infested districts.

Condimental stock foods or *tonics* are unnecessary in the efficient feeding of dairy cattle. In two Michigan trials there was no benefit whatsoever from the addition of a widely-used stock tonic to a simple ration of legume hay, corn silage, and a mixture of corn, barley, oats, linseed meal and cottonseed meal.[174] In fact, the feeding of the stock tonic according to the directions of the manufacturers caused some of the cows to go off feed and produced bloating in several cases.

Certain *drugs* have been supposed by some dairymen to increase the yield of milk or fat, and occasionally attempts have been made by unscrupulous persons to increase the yields of cows on official test by the use of drugs. In most of the tests of such products there has been no decided increase in the yield of milk or fat over a 24-hour period.[175] Often, "drugging" a cow has resulted in a marked decrease in yield instead of an increase. The effect of thyroprotein on milk production has been discussed previously. (1051)

1067. Flavor and odor of milk.—Because of the importance of the flavor and odor of milk, numerous studies have been made of the effects of various feeds on the palatability of milk and its products.[176] In the case of most feeds which affect the flavor or odor of milk, the effect, at least in a well-ventilated barn, is produced chiefly by substances carried in the blood to the udder, and not by odors absorbed by the milk from the stable air. Tests have shown that the flavor may be affected not only when a cow eats the feed, but even when she inhales the odor of the feed. An off-flavor caused by feed can usually be prevented or at least greatly lessened by feeding the particular feed only immediately after milking. Since most compounds that produce off-flavors are volatile, they will largely pass off before the next milking.

The most marked off-flavor is produced by garlic, onions, the cruciferae (including turnips, cabbage, rape, and kale), and certain weeds, including bitterweed (*Helenium tenuifolium*) and French weed or stinkweed (*Thlaspi arvense*). Green alfalfa, green sweet clover, and legume silage may also cause a pronounced flavor if fed within 5 hours before milking. Corn silage, green corn, green rye, or potatoes may produce a less marked effect if fed before milking. Even alfalfa hay may cause a noticeable flavor if fed less than 4 hours before milking. When cows are first turned to pasture, a grass flavor is at once noticed in the milk, but this soon disappears, or else we then fail to notice it.

Heating the milk to 145° F. and aerating it or blowing air through it usually removes much of any objectionable feed odor or flavor, and may entirely eliminate slight taints. If a pasture is infested with leeks or wild onions, a pronounced taint may usually be avoided by grazing the cows on the pasture only 2 or 3 hours immediately after milking.

Sometimes, especially late in the lactation period, a cow gives milk which tastes rancid or bitter after standing a short time. This rarely happens when the cow receives green feed. The trouble is caused by an

enzyme in the milk that acts on the fat. It can be prevented by heating the milk, immediately after milking, enough to destroy the enzyme, and then cooling it.

On storage, milk sometimes develops an off-flavor known as oxidized, cardboard, or tallowy flavor, due to changes in unstable constituents of the milk. Homogenized milk has less tendency to develop oxidized flavor, but on exposure to light is much more susceptible to another type of off-flavor. Experiments are being conducted by dairy scientists to find practical methods of treating or handling milk to reduce trouble from these off-flavors. There seems to be less tendency for oxidized flavor to occur when cows are fed some kinds of roughage. In New York tests, less oxidized flavor developed with orchard grass pasture or birdsfoot trefoil hay than with Ladino clover pasture or hay.[177]

QUESTIONS

1. Compare the efficiency of dairy cows and beef steers in the production of human food.
2. What do dairy-herd-improvement-association records show concerning the relative income above feed cost from high-producing cows and from low producers?
3. Why are high producers more efficient than low producers in converting feed into milk?
4. How is the amount of 4 per cent fat-corrected milk computed?
5. What is the approximate gross efficiency of dairy cows yielding about 10,000 lbs. of 4 per cent fat-corrected milk a year?
6. Why does scanty feeding reduce the efficiency of cows of high productive capacity?
7. Describe the results that have been secured in experiments in which purebred bulls have been used to develop a good herd from scrubs.
8. Compare dairy cows and beef-type cows in efficiency of milk production; compare purebred and grade dairy cows.
9. How does size of cow affect milk yield?
10. Discuss the importance of records of production in building up a profitable dairy herd.
11. What are dairy-herd-improvement associations; owner-sampler clubs?
12. Which is the better measure of the productive ability of a dairy herd—official tests of selected cows, or consecutive yearly herd tests of all the cows?
13. State 6 nutrient requirements of dairy cows for efficient production.
14. Why is not the common "thumb rule" as accurate a guide as the grain feeding tables, for determining the amounts of concentrates needed by individual cows?
15. Why must feeding standards recommend slightly greater amounts of nutrients than dairy cows actually require?
16. How much digestible protein and how much total digestible nutrients should be provided for maintaining a 1,000-lb. dairy cow?
17. Discuss the amount of protein required by dairy cows for milk production.
18. Show by an example how the protein content of the concentrate mixture for dairy cows should depend on the protein content of the roughage.
19. About what percentage of protein should a concentrate mixture contain for feeding with good mixed clover-and-timothy hay and corn silage?
20. Discuss quality of protein in dairy rations.
21. Under what conditions should urea be used as a partial protein substitute?
22. Discuss the fat requirements of dairy cows.
23. Why is a range indicated in the amounts of total digestible nutrients recommended in the Morrison feeding standards for milk production?
24. Discuss the replacing of concentrates by high-quality roughage.
25. What are the two points of view concerning the need of a lactation factor for high milk production?
26. Discuss the results of the "input-output" experiments in which increasing amounts of concentrates have been added to the rations of good cows.
27. What factors determine the level of concentrate feeding that will be most profitable?
28. Discuss the feeding of good dairy cows on roughage alone.
29. Tell about the Indiana demonstration which showed that it pays to feed good cows liberally.
30. Under what conditions may it be economical to restrict the amount of roughage fed dairy cows?
31. What is the relative value per pound of good hay and of a good concentrate mixture for milk production?

32. What is the effect of feeding cows only 2 to 4 lbs. of hay and no other roughage?
33. What is the effect of including ground alfalfa hay in a dairy concentrate mixture?
34. What are the salt requirements of dairy cows?
35. Under what specific conditions should a phosphorus supplement be added to the rations of dairy cows?
36. When would you add a calcium supplement to dairy rations?
37. Discuss the losses and storage of calcium and phosphorus by dairy cows.
38. What results have been secured when calcium and phosphorus supplements have been added to good dairy rations?
39. Discuss trace mineral supplements for dairy cows.
40. Discuss the vitamin requirements of dairy cows.
41. When may deficiencies of vitamin A occur?
42. Discuss the effect on the vitamin A value of milk and butter of: (a) Breed of cow; (b) the ration fed.
43. What is the effect of adding a vitamin supplement to a good dairy ration?
44. What have experiments shown concerning any need of adding a vitamin D supplement to ordinary dairy rations?
45. Discuss the use of mineral or vitamin supplements to prevent breeding troubles.
46. Discuss the water requirements of dairy cows, considering: (a) Amount required; (b) use of drinking bowls.
47. Is it beneficial to add an antibiotic feed supplement to rations for dairy cows?
48. Discuss the use of thyroprotein in dairy rations.
49. Discuss the grinding of grain for dairy cows; the chopping or grinding of hay.
50. About how much fat, protein, lactose, and mineral matter does cow's milk contain?
51. What are some of the factors which affect the yield and composition of milk?
52. Discuss the effect upon yield and composition of milk of any of the factors considered in Articles 1055 to 1067 which are assigned by your instructor.

REFERENCES

1. Cooper and Spillman, U.S.D.A. Farmers' Bul. 877.
2. U.S.D.A. Dairy Herd-Improvement-Assoc. News Letter, 29, 1953, No. 9.
3. Eckles and Reed, Mo. Res. Bul. 2.
4. Headley, Nev. Sta., Rpt. at Western Division of Amer. Dairy Sci. Assoc., 1947, and mimeo. rpt.
5. Swett, Matthews, and Fohrman, U.S.D.A. Tech. Bul. 1123; N.J. Rpt. 1951.
6. Gaines, Ill. Bul. 308; Overman and Gaines, Ill., Jour. Anim. Sci., 7, 1948, pp. 55–59; see also: Musgrave and Salisbury, Ill., Jour. Dairy Sci., 35, 1952, pp. 174–178.
7. Brody, Bioenergetics and Growth, 1945.
8. Kildee, Weaver, et al., Iowa Buls. 165, 188, 251; Jour. Dairy Sci., 4, 1921, pp. 12–23; Bergh, Minn. Ext. Cir. 15; McGilliard, Weaver, and Kuhlman, Okla. Rpt. 1936–38; Olson et al., S.D. Buls. 198, 206; Baird, Hilton, and Rothwell, Can. Dept. Agr. Bul. 126.
9. Harvey and Lush, Iowa, Jour. Dairy Sci., 9, 1950, p. 638; Rennie, Iowa, Sci. Agr. (Canada), 31, 1951, pp. 553–558; Bartlett, Pfau, and Shuart, N.J. Rpt. 1949; Freeman and Dunbar, W. Va., Jour. Dairy Sci., 37, 1954, p. 667; Tyler, Corky, and Heizer, Wis., Jour. Anim. Sci., 1955, p. 1189; Stone, Rennie, and Raithby, Canada, Jour. Dairy Sci., 38, 1955, pp. 616–617; see also: Kelly, Davis, and Lawritson, Nebr., Jour. Dairy Sci., 37, 1954, pp. 666–667.
10. Swett and Matthews, U.S.D.A., Jour. Dairy Sci., 36, 1953, p. 584; Swett, U.S.D.A. Agr. Res., 2, 1953, No. 3.
11. McDowell, U.S.D.A., Dairy-Herd-Improvement Assoc. Letter, Nov. 1932.
12. Burke and Ainslie, N.Y., mimeo. rpt., 1956.
13. Bierly, N.Y. (Cornell) Bul. 804; see also: Brody and Ragsdale, Mo. Bul. 351.
14. Gaines, Ill., Jour. Dairy Sci., 14, 1931, pp. 14–25; Brody, Mo. Res. Bul. 366.
15. Gaines, Ill., Jour. Dairy Sci., 23, 1940, pp. 71–75; 23, 1940, pp. 259–265; 29, 1946, pp. 259–272; Gaines, Rhode, and Cash, Jour. Dairy Sci., 25, 1942, pp. 15–18; Musgrave and Gaines, Ill., Jour. Dairy Sci., 31, 1948, pp. 119–122; Davis and Morgan, Nebr. Rpt. 1943; Davis, Morgan, and Gaines, Jour. Dairy Sci., 26, 1943, pp. 625–641; Gaines, Davis, and Morgan, Jour. Dairy Sci., 30, 1947, pp. 273–278.
16. Kleiber and Mead, Cal., Jour. Dairy Sci., 28, 1945, pp. 49–55; Brody, Mo., Bioenergetics and Growth, 1945.
17. Woodward, Shepherd, and Graves, U.S.D.A. Misc. Pub. 130; see also: Fraser, Dairy Farming, pp. 140–146; Headley, Nev. Bul. 116.
18. Hills et al., Vt. Bul. 225.
19. Haecker, Minn. Buls. 71, 79, 140.
20. Eckles, Mo. Res. Bul. 7.
21. Armsby, The Nutrition of Farm Animals.
22. Forbes, Fries, and Kriss, Penn., Jour. Dairy Sci., 9, 1926, pp. 15–27; Forbes and Kriss, Penn., Amer. Soc. Anim. Prod., Proc. 1931, 1932.
23. Brody and Proctor, Mo. Res. Bul. 222.
24. Summarized by Kriss, Penn., Jour. Nutr., 4, 1931, pp. 141–161.
25. Loosli, Becker, Huffman, Phillips, and Shaw, Nutrient Requirements of Domestic Animals, III, Nutrient Requirements of Dairy Cattle, Revised, 1956.
26. McMeekan, New Zealand, Report at 6th International Grasslands Congress, 1952.
27. Haecker, Minn. Buls. 71, 79, 140; see also: Savage, N.Y. (Cornell) Bul. 323; Bartlett,

Foot, Huthnance, and Mackintosh, Jour. Dairy Res., England, 11, 1940, pp. 121–135.
28. Armsby, The Nutrition of Farm Animals.
29. Hansson, Utfodringslära; Möllgaard, Fütterungslehre des Milchviehs; Eckles, Mo. Res. Bul. 7; Ellett, Holdaway, and Harris, Va. Tech. Bul. 23; Kriss, Penn., Jour. Nutr., 4, 1931, pp. 141–161.
30. Hills et al., Vt. Bul. 225.
31. Hart and Humphrey, Wis., Jour. Biol. Chem., 38, 1919, pp. 515–527; 44, 1920, pp. 189–201; 48, 1921, pp. 305–311; Morrison, Hulce, and Humphrey, Wis. Bul. 352; Hart and Humphrey, Wis. Bul. 417; Forbes and Swift, Penn., Jour. Dairy Sci., 8, 1925, pp. 15–27; Fries, Braman, and Kriss, Penn., Jour. Dairy Sci., 7, 1924, pp. 11–23; Forbes and Kriss, Penn., Amer. Soc. Anim. Prod., Proc. 1931, 1932.
32. Harrison and Savage, N.Y. (Cornell) Bul. 540; Harrison, Savage, and Work, N.Y. (Cornell) Bul. 578.
33. Work, Ph.D. thesis, Cornell University.
34. Perkins, Ohio Bimo. Bul. 147.
35. U.S.D.A., Rpts. of Chief of Bur. Dairy Industry, 1947, 1949; Moore, U.S.D.A., mimeo. rpt.; Moore, Hoard's Dairyman, Feb. 10, 1953.
36. Cary and Meigs, U.S.D.A., Jour. Agr. Res., 9, 1924, p. 603; Cary, U.S.D.A., Jour. Dairy Sci., 18, 1935, p. 445.
37. Darnell and Shepardson, Tex. Rpt. 1941; Henke, Hawaii Bul. 95; see also: Nodland and Pond, Minn. Bul. 378.
38. Perkins and Monroe, Ohio Bul. 376; Perkins, Ohio Buls. 389, 532; Ohio Spec. Cirs. 29, 43; Perkins, Jour. Dairy Sci., 18, 1935, pp. 445–446.
39. Hilton, Wilbur, and Epple, Ind. Bul. 407; Mich. Rpt. 1932–34; Caldwell, Ohio Bul. 267; Dawson et al., U.S.D.A. Cir. 696.
40. Morrison, Hulce, and Humphrey, Wis., Amer. Soc. Anim. Prod., Proc. 1922, pp. 68–72; Wis. Buls. 339, 352; Hart and Humphrey, Wis. Bul. 417; Gardner, Ill., Jour. Dairy Sci., 33, 1950, p. 389; see also: Iowa Rpt. 1924; N.J. Rpt. 1950; Savage, Harrison, and Work, N.Y. (Cornell) Rpt. 1936; Monroe and Hayden, Ohio Bimo. Bul. 158; Olson, S.D. Rpts. 1922, 1933.
41. Hart and Humphrey, Wis., Jour. Biol. Chem. 38, 1919, pp. 515–527; 44, 1920, pp. 189–201; Wis. Bul. 417.
42. Montavon, Ill., Jour. Dairy Sci., 37, 1954, pp. 905–909.
43. Morrison, Bratton, and Salisbury, N.Y. (Cornell) Rpt. 1942; Bratton, Salisbury, and Morrison, Jour. Dairy Sci., 26, 1943, pp. 730–731; see also: Branton, Rusoff, and Seath, La. Dairy Res. Digest, 1, 1943, No. 3; Swanson and Herman, Mo. Res. Bul. 372; Maynard, Miller, and Krauss, N.Y. (Cornell) Memoir 113.
44. Rupel, Bohstedt, and Hart, Wis., Jour. Dairy Sci., 24, 1941, pp. 333–337.
45. Hart and Humphrey, Wis., Jour. Biol. Chem., 21, 1915, p. 239; 26, 1916, p. 457; 31, 1917, p. 445; 35, 1918, p. 367.
46. Morris, Wright, and Fowler, Jour. Dairy Res., England, 7, 1936, pp. 97–121; Morris and Ray, Jour. Dairy Res., 10, 1939, pp. 165–185.
47. For a review of the numerous investigations on urea for dairy cattle, see Reid, N.Y., Jour. Dairy Sci., 36, 1953, pp. 955–996; see also: Henke, Otagaki, and Nordfeldt, Hawaii Rpt. 1948–50; Parham, Frye, Kilpatrick, and Rusoff, La., Jour. Dairy Sci., 38, 1955, pp. 664–668; Archibald, Kinsman, and Kuzmeski, Mass. Bul. 475; Ward, Huffman, and Duncan, Mich., Jour. Dairy Sci., 38, 1955, pp. 298–302; Davis, Williams, and Loosli, N.Y., Jour. Dairy Sci., 37, 1954, pp. 813–818; Bohman, Trimberger, Loosli, and Turk, N.Y., Jour. Dairy Sci., 37, 1954, pp. 284–293; Davis, Trimberger, Turk, and Loosli, N.Y. (Cornell) Bul. 914; Thompson, Graf, Eheart, and Holdaway, Va., Jour. Dairy Sci., 35, 1952, pp. 1010–1016; Breirem, Royal Agr. Col., Norway, Rpt. at European Nutrition Conference, England, July, 1946; Brouwer Univ. of Wageningen, Holland, Rpt. at European Nutrition Conference, England, July, 1946; Bowstead and Fredeen, Canada, Sci. Agr., 28, 1948, pp. 66–78.
48. Maynard and McCay, N.Y. (Cornell) Bul. 543; Maynard, McCay, Williams, and Madsen, N.Y. (Cornell) Bul. 593; Maynard, Loosli, and McCay, N.Y. (Cornell) Bul. 753; Lucas, Loosli and Maynard, N.Y (Cornell) Memoir 251; Loosli, Maynard, and Lucas, N.Y. (Cornell) Memoir 265; Maynard, Gardner, and Hodson, N.Y. (Cornell) Bul. 722; Loosli and Maynard, N.Y. Farm Res., 11, 1945, No. 4.
49. Henke and Otagaki, Hawaii Rpt. 1946–48; Otagaki and Henke, Hawaii Rpt. 1948–50; Cannon, Hansen, and Espe, Iowa Rpt. 1937; Md. Buls. A-78, A-81; Gibson and Huffman, Mich. Quar. Bul., 21, 1939, No. 4; Schubert and Wells, Mich. Quar. Bul., 23, 1940, No. 2; Monroe and Krauss, Ohio Bul. 644; Monroe and Krauss, Ohio Bimo. Bul. 226; Byers, Jones, and Haag, Ore., Jour. Dairy Sci., 32, 1949, pp. 596–603; Dykstra, Dammers, and Frens, Versl. Landbouwk. Onderzoek., 59, 1953, p. 6.
50. Stull and Harlan, Progressive Agr. in Ariz., 7, 1955, No. 2.
51. Bloom et al., Iowa, Jour. Dairy Sci., 38, 1955, p. 614; Irvin, Shaw, Saarinen, and Moore, Md. and U.S.D.A., Jour. Anim. Sci., 10, 1951, pp. 947–960; Loosli, Davis, and Warner, N.Y., Jour. Dairy Sci., 38, 1955, pp. 797–804; see also: Martin, Stoddard, and Allen, Iowa, Jour. Dairy Sci., 37, 1954, pp. 1233–1240.
52. Brody, Bioenergetics and Growth, 1945, p. 840; Gaines, Ill., Jour. Anim. Sci., 2, 1943, pp. 304–313; see also: Haecker, Minn. Buls. 71, 79, 140; Savage, N.Y. (Cornell) Bul. 323; Armsby, The Nutrition of Farm Animals; Hansson, Utfodringslära; Möllgaard, Füttungslehre des Milchviehs; Forbes and Kriss, Penn., Amer. Soc. Anim. Prod., Proc. 1931, 1932.
53. Crandall, Cornell Univ., information to the author; N.Y. Dairy Herd Improver, 26, 1943, No. 6; see also: McIntyre and Ragsdale, Mo. Bul. 488; Monroe and Livezey, Ohio Bul. 662; Wylie and Neel, Tenn. Bul. 163.
54. U.S. Dept. Agr., special circular.
55. Kitchen, Paisley, and Bender, N.J. Bul. 758.
56. Huffman et al., Mich. Sta., Jour. Dairy Sci., 21, 1938, pp. 101–102; 23, 1940, p. 559; 27, 1944, pp. 821–833; 29, 1946, p. 542; 32, 1949, pp. 465–474; 33, 1950, pp. 710–720; 35, 1952, pp. 30–50; 35, 1952, pp. 1001–1009; 37, 1954, pp. 957–966.
57. Byers, Smith, and Jones, Ore., Jour. Dairy Sci., 27, 1944, p. 635; Smith, Jones, and Haag, Ore., Jour. Dairy Sci., 28, 1945, pp. 343–354; Bowling and Van Landingham, West

Va. Bul. 298; Davis and Kemmerer, Ariz., Jour. Dairy Sci., 31, 1948, pp. 973–975; see also: Kendall and Engberson, Ill., Jour. Dairy Sci., 33, 1950, p. 388.

58. Saarinen, Sami, Shaw, and Moore, Md. and U.S.D.A., Jour. Dairy Sci., 34, 1951, pp. 287–294; Irvin, Shaw, Saarinen, and Moore, Md. and U.S.D.A., Jour. Anim. Sci., 10, 1951, pp. 947–960; Loosli, Davis, and Warner, N.Y., Jour. Dairy Sci., 38, 1955, pp. 797–804.

59. Jensen, Klein, Rauchenstein, Woodward, and Smith, U.S.D.A. Tech. Bul. 815; Baker and Tomhave, Del. Bul. 248; Hilton, Wilbur, Bratton, and Epple, Ind. Rpts. 1938, 1939, 1940; Autrey, Cannon, and Espe, Iowa Res. Bul. 305; Md. Rpts. 1939, 1940, 1942; Moore, and Cowsert, Miss. Bul. 383; Headley, Nev. Bul. 172; Headley, Nev., Jour. Anim. Sci., 4, 1945, pp. 367–372; Borland, Beam, and Jones, Penn. Bul. 424; Graves, Bateman, Shepherd, and Caine, U.S.D.A. Tech. Bul. 724; see also: Henke, Hawaii Rpt. 1950–52; Martin, Stoddard, and Allen, Iowa, Jour. Dairy Sci., 37, 1954, pp. 1233–1240; Nodland and Pond, Minn. Bul. 378; Morrow, Keener, and Hall, N.H. Tech. Bul. 86; Tennant and Fowler, R.I. Bul. 279; Blanch and Broadbent, Utah Bul. 309; Willard, Wyo. Buls. 182, 202.

60. Reid, N.Y., paper at meeting of Amer. Dairy Sci., Assoc., 1955.

61. Pratt, Ohio Farm and Home Res. 294; see also: Wilt and Hoglund, Mich. Spec. Bul. 383.

62. Cannon, Hansen, and Espe, Iowa Rpt. 1939, Part I; Reed, Fitch, and Cave, Kan. Bul. 233; McIntyre and Ragsdale, Mo. Bul. 488; Headley, Nev. Buls. 119, 140, 172; Headley, Willhite and Miller, Nev. Rpt. 1948; Jones, Brandt, and Haag, Ore. Buls. 328, 359; Sherwood and Dean, Ore. Bul. 380; Sherwood and Jones, Ore. Bul. 462; Bateman, Utah Farm and Home Sci., 2, 1941, No. 4; Hodgson, Knott, Miller, and Murer, Wash. Buls. 366, 386; Hodgson, Knott, and Wolberg, Wash. Bul. 394; Wolberg, Spielman, Miller, and Ashworth, Wash., Jour. Dairy Sci., 27, 1944, pp. 630–631; Wolberg, Lundquist, Miller, and Ashworth, Wash. Buls. 455, 470; Willard, Wyo. Bul. 237; Headley, Knight, and Cline, U.S.D.A. Cir. 352; Moseley, Stuart, and Graves, U.S.D.A. Tech. Bul. 116; Graves et al., U.S.D.A. Tech. Bul. 610.

63. Woodward, Amer. Soc. Anim. Prod., Proc. 1940.

64. Lundquist, Wilbur, and Mott, Ind. Rpt. 1953.

65. Hazlewood, Tenn. Cir. 68, Tenn. Bul. 207.

66. Fairchild and Wilbur, Ind. Bul. 277; see also: Hanson and Schaefer, Minn. Spec. Bul. 123; Ohio Bul. 373.

67. Monroe and Krauss, Ohio. Bul. 644; Stoddard, Allen, and Peterson, Wis., Jour. Anim. Sci., 8, 1949, pp. 630–631; Tyznik and Allen, Wis., Jour. Dairy Sci., 34, 1951, p. 493; Van Soest, Allen, and Maki, Wis., Jour. Dairy Sci., 37, 1954, pp. 660–661; Cox, England, Jour. Dairy Res., 20, 1953, pp. 1–12; Balch et al., England, Jour. Dairy Res., 21, 1954, pp. 165, 172, 305; 22, 1955, pp. 10–15; see also: Martin, Stoddard, and Allen, Iowa, Jour. Dairy Sci., 37, 1954, pp. 1233–1240.

68. Becker et al., Fla., Jour. Dairy Sci., 38, 1955, pp. 618–619.

69. Nevens, Ill. Bul. 289; Hunt, Va. Rpt. 1918.

70. Harshbarger, Ill., Jour. Dairy Sci., 35, 1952, p. 501; Baker, La., Jour. Dairy Sci., 38, 1955, pp. 614–615.

71. For more detailed information on the mineral requirements of dairy cattle, see the following reviews: Bohstedt, Jour. Dairy Sci., 25, 1942, pp. 441–458; Maynard and Loosli, Annual Review of Biochemistry, 12, 1943, pp. 251–273; Forbes et al., Penn. Bul. 319.

72. Smith, N.Y. Farm Res., 17, 1951, No. 3; Smith, Lengemann, and Reid, N.Y., Jour. Dairy Sci., 36, 1953, pp. 762–765; Smith, Aines, and Turk, N.Y., mimeo. rpt.; Smith, Hoard's Dairyman, July 10, 1955; see also: Babcock and Carlyle, Wis. Rpt. 1905.

73. Huffman, Duncan, Robinson, and Lamb, Mich. Tech. Bul. 134; see also: Jones, Haag, and Brandt, Ore. Bul. 329.

74. Van Landingham, Henderson, and Bowling, West Va., Jour. Dairy Sci., 19, 1939, pp. 597–609.

75. Colovos, Keener, Teeri, and Davis, N.H. Buls. 394, 409.

76. Hart, Keenan, and Humphrey, Wis. Bul. 425; Hart, Hadley, and Humphrey, Wis. Res. Bul. 112.

77. Palmer, Fitch, Gullickson, and Boyd, Minn., Cornell Vet., 25, 1935, pp. 229–246.

78. Converse, U.S.D.A. Tech. Bul. 1092; see also: Va. Rpt. 1947–49.

79. Becker et al., Fla. Bul. 513; Becker, Neal, and Shealy, Fla. Bul. 262; Rusoff, La., Jour. Anim. Sci., 9, 1950, pp. 666.

80. Forbes et al., Ohio Buls. 295, 308, 330, 363; Miller, Yates, Jones, and Brandt, Ore., Amer. Jour. Physiol., 72, 1925, pp. 647–654; 75, 1926, pp. 696–703; see also: Visek, Monroe, Swanson, and Comar, Tenn., Jour. Dairy Sci., 36, 1953, pp. 373–384.

81. Forbes et al., Penn. Bul. 319; Ellenberger, Newlander, and Jones, Vt. Buls. 331, 342, 360, 380, 396; see also: Mather, N.J., Jour. Dairy Sci., 38, 1955, p. 626.

82. Eaton, Ala. Rpts. 1930, 1931, 1932; Cunningham and Davis, Ariz. Rpts. 1923, 1927; Baker, Del. Bul. 133; Iowa Rpts. 1925, 1927; Rusoff, Seath, and Bahm, La. Rpts. 1944, 1945; Lindsey and Archibald, Mass. Buls. 230, 255; Reid and Huffman, Mich. Tech. Bul. 105; Palmer and Gullickson, Minn., Jour. Dairy Sci., 24, 1941, pp. 519–520; Miss. Rpt. 1944; Hayden, Monroe, and Crawford, Ohio Bimo. Bul. 145; Ohio Spec. Cir. 29; Bechdel, Williams, Shigley, and Borland, Penn. Bul. 395; Copeland, Texas Rpt. 1943; Newlander and Ridell, Vt. Pamphlet 25; Holdaway, Ellett, Eheart, and Pratt, Va. Tech. Bul. 65; Hart, Hadley, and Humphrey, Wis. Res. Bul. 112; McCandish, Scot. Jour. Agr., 8, 1925, No. 1, pp. 55–59.

83. Norton, R.I. Rpt. 1949.

84. Bentley, Quicke, Kastelic, and Phillips, Wis., Jour. Dairy Sci., 34, 1951, pp. 363–366; Bentley and Phillips, Wis., Jour. Dairy Sci., 34, 1951, pp. 396–403; see also: Mather and Bender, N.J. Rpt. 1949; Hawkins et al., N.C., Jour. Dairy Sci., 38, 1955, pp. 536–547.

85. Eckles and Williams, Minn., Jour. Dairy Sci., 8, 1925, pp. 89–93; Norton, N.Y., Jour. Dairy Sci., 28, 1945, pp. 927–932; see also: Loosli and Lucas, N.Y., Jour. Dairy Sci., 26, 1943, pp. 291–294; Holdaway, Ellett, Eheart, and Pratt, Va. Tech. Bul. 65.

86. Reid, Huffman, and Duncan, Mich., Jour.

Nutr., 30, 1945, pp. 413–423; Baker, N.Y. (Cornell) Vet. Col. Rpt. 1941.
87. Duncan, Huffman, Mitchell, and Reid, Mich., Jour. Dairy Sci., 27, 1944, p. 636; Cole, Rasmussen, and Thorp, Mich., Vet. Med., 39, 1944, pp. 204–206.
88. Adams, Gullickson, Sauter, and Gander, Minn., Jour. Dairy Sci., 37, 1954, p. 655; Safford, Swingle, and Marsh, Mont., Amer. Jour. Vet. Res., 15, 1954, p. 373; Blaxter et al., Scotland, Brit. Jour. Nutr., 6, 1952, pp. 125–144; 7, 1953, pp. 105–123.
89. Wise, Cannon, and Thomas, Iowa Rpt. 1948.
90. Kuhlman and Gallup, Okla., Jour. Dairy Sci., 24, 1941, pp. 522–523; 25, 1942, pp. 688–689; Ronning, Berousek, Kuhlman, and Gallup, Okla., Jour. Dairy Sci., 36, 1953, pp. 52–56; Byers, Weswig, Bone, and Jones, Ore., Jour. Dairy Sci., 38, 1955, pp. 657–663; Copeland and Fraps, Tex. Rpts. 1939, 1940, 1941; Davis and Madsen, U.S.D.A., Jour. Nutr., 21, 1941, pp. 135–146.
91. Jones, Dougherty, and Haag, Ore. Bul. 395.
92. Hart, McCollum, Steenbock, and Humphrey, Wis. Res. Bul. 17; Hart, Steenbock, and Humphrey, Wis. Res. Bul. 49; Hart et al., Wis. Buls. 373, 405.
93. Kuhlman and Gallup, Okla. Rpt. 1936–38.
94. Cunningham and Addington, New Mex. Bul. 257.
95. Halverson, Hostetler, Foster, and Sherwood, N.C., Jour. Nutr., 18, 1939, pp. 285–296.
96. Davis and Hathaway, Nebr. Res. Bul. 54; Hathaway and Davis, Nebr. Res. Bul. 69; Sutton and Krauss, Ohio Bimo. Bul. 178; Shaw, Bechdel, Guerrant, and Dutcher, Penn., Jour. Dairy Sci., 20, 1927, pp. 521–535; Mitchell and Wise, S.C. Rpt. 1944; Baumann, Steenbock, Beeson, and Rupel, Wis., Jour. Biol. Chem., 105, 1934, pp. 167–176; Beeson, Wis., Amer. Soc. Anim. Prod., Proc. 1934, pp. 54–56.
97. Hilton, Wilbur, and Hauge, Ind., Jour. Dairy Sci., 27, 1944, pp. 57–62.
98. Koehn and Salmon, Ala. Bul. 266; Brence and Nelson, Mont., Jour. Dairy Sci., 34, 1951, pp. 960–965; Ohio Bul. 680.
99. U.S.D.A. Misc. Pubs. 571, 636. References are given in the latter publication to the reports issued by various experiment stations which cooperated in the investigation.
100. Fraps, Copeland, Treichler, and Kemmerer, Tex. Bul. 536; Deuel, Hallman, Johnston, and Mattson, Jour. Nutr., 23, 1942, pp. 567–579.
101. Rusoff, Skipper, and Dix Arnold, Fla., Jour. Dairy Sci., 25, 1942, pp. 807–813; Fountaine and Bolin, Id., Jour. Dairy Sci., 27, 1944, pp. 155–158; Jensen, Boyer, Phillips, Rupel, and Lundquist, Wis., Jour. Dairy Sci., 25, 1942, pp. 931–937.
102. Archibald and Parsons, Mass. Bul. 357; Md. Rpt. 1944; Deuel, Hallman, Johnston, and Mattson, Jour. Nutr., 22, 1941, pp. 303–313; Wilson, Cert. Milk, 17, 1942, No. 197, p. 5; 19, 1944, No. 223, p. 3.
103. Olson and Wallis, S.D. Bul. 296; Wallis, S.D. Rpts., 1941, 1942, 1943; Wallis, S.D. Bul. 372.
104. Wallis, S.D. Bul. 372.
105. Archibald and Neville, Mass. Bul. 398.
106. Krauss, Monroe, Hayden, and Edginton, Ohio, Jour. Dairy Sci., 22, 1939, pp. 440–441.
107. Ellenberger, Newlander, Jones, et al., Vt. Buls. 407, 425, 475, 495, 508, 520, 561, 576, and Vt. Rpt. 1945.
108. Eaton et al., N.Y., Jour. Dairy Sci., 30, 1947, pp. 787–794.
109. Hart, Hadley, and Humphrey, Wis. Res. Bul. 112.
110. Archibald, Mass. Buls. 355, 369, 378; Lucas, Loosli, and Maynard, N.Y. (Cornell) Memoir 251.
111. Davis and Hathaway, Nebr., Jour. Dairy Sci., 19, 1936, pp. 439–440.
112. White and Johnson, Conn. (Storrs) Bul. 198; Atkeson, Warren, and Anderson, Id., Jour. Dairy Sci., 17, 1934, pp. 265–277; Cannon, Hansen, and O'Neal, Iowa Bul. 292; Moore and Bowling, Mich. Quar. Bul., 13, 1930, No. 1; Fuller, N.H. Tech. Bul. 35; Collier N.Y. (Geneva) Rpt. 1893; Perkins and Monroe, Ohio, Jour. Dairy Sci., 8, 1925, pp. 409–414; Henderson and Morrow, West Va. Bul. 256; Armsby, Wis. Rpt. 1886; Woodward and McNulty, U.S.D.A. Tech. Bul. 278; Kelley and Rupel, U.S.D.A. Tech. Bul. 591.
113. Woodward and McNulty, U.S.D.A. Tech. Bul. 278; Cannon, Hansen, and O'Neal, Iowa Bul. 292; White and Johnson, Conn. (Storrs) Bul. 198.
114. Dow, Maine Bul. 429; see also: Rauchenstein and Watson, Maine Bul. 408.
115. Garver and Knott, Wash. Bul. 291.
116. Regan and Mead, Cal., Jour. Dairy Sci., 22, 1939, pp. 472–473.
117. Jacobson, Miles, and McGilliard, Iowa, Jour. Dairy Sci., 37, 1954, p. 657; Jacobson and Porter, Iowa Farm Sci., 10, 1955, No. 5; Bartley, Fountaine, and Atkeson, Kan., Jour. Dairy Sci., 36, 1953, pp. 402–408; Rusoff and Haq, La., Jour. Dairy Sci., 37, 1954, pp. 677–683.
118. Ulberg et al., Wis. Bul. 500.
119. For reviews on thyroprotein for dairy cows, see: Thomas, U.S.D.A., Nat. Res. Council Pub. 266, 1953; Blaxter, Reineke, Crampton, and Petersen, Jour. Anim. Sci., 8, 1949, pp. 307–352. For later data see: Swanson, Tenn. Farm and Home Sci., No. 7, 1953; Swanson, Tenn., Jour. Dairy Sci., 37, 1954, pp. 1212–1219; Swanson, Monroe, and Comar, Tenn., Jour. Dairy Sci., 37, 1954, pp. 659, 660; Henderson, West Va. Bul. 357, Part 1; Thomas and Okamoto, U.S.D.A., Jour. Dairy Sci., 37, 1954, p. 660; Thomas et al., U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 877–888; Leech and Bailey, Jour. Agr. Sci., England, 43, 1953, p. 236; Chanda, McNaught, and Owen, Scotland, Biochem. Jour., 51, 1952, pp. 543–552; Aitken, Boyne, and Crichton, Scotland, Jour. Dairy Res., 20, 1953, p. 291.
120. Thomas and Moore, U.S.D.A., Jour. Dairy Sci., 36, 1953, pp. 657–672.
121. Nat. Res. Council Pub. 266, 1953.
122. Millen, Nevens, and Gardner, Ill., Jour. Anim. Sci., 7, 1948, p. 543; Mukherjee and Mitchell, Ill., Jour. Anim. Sci., 10, 1951, pp. 149–162; Reece, N.J., Jour. Dairy Sci., 33, 1950, p. 387.
123. Olson, S.D. Bul. 358 and Cir. 34; Bohstedt, Roche, Fargo, Rupel, and Duffee, Wis. Bul. 421.
124. Colovos, Keener, Davis, Morrow, and Gibson, N.H. Bul. 419; Turk, N.Y., Proc. 1953 Cornell Nutr. Conf.; Davis, Loosli, and Grippin, N.Y., Jour. Anim. Sci., 12, 1953, p. 913.
125. Dalton, Huffman, and Ralston, Mich., Jour. Dairy Sci., 36, 1953, pp. 1279–1284.
126. Forbes, Fries, and Braman, Penn., Jour. Agr.

Res., 31, 1925, pp. 987–995; Bechdel, Williams, and Jeffries, Penn. Rpt. 1927; Olson, S.D. Bul. 252.

127. Nevens, Ill. Rpts. 1926, 1927; Wilbur, Hilton, and Mayer, Ind. Rpt. 1927, and mimeo. rpt.; Weaver, Ely, and Mathews, Iowa Leaflet 76; Ingham and Meade, Md. Bul. 316; Reed and Burnett, Mich. Quar. Bul. 9, 1926, No. 1; Moore and Cowsert, Miss. Bul. 235; Tretsven, Mont. Bul. 282; Hayden, Monroe, and Perkins, Ohio Bul. 502; Forbes, Fries, and Braman, Penn., Jour. Agr. Res., 31, 1925, pp. 987–995; Bechdel, Williams, and Jeffries, Penn., Rpt. 1927; Morrow and LaMaster, S.C. Bul. 255; Olson, S.D. Bul. 252; Morrison, Humphrey, Rupel, et al., Wis. Buls. 388, 396; Rupel, Roche, and Bohstedt, Wis. Res. Bul. 102.

128. Jones, Brandt, and Haag, Ore. Bul. 328; Tretsven, Mont. Bul. 282; Headley, Nev. Rpt. 1934.

129. Powell, Amer. Soc. Anim. Prod., Proc. 1938; Powell, Jour. Dairy Sci., 22, 1939, pp. 453–454; 24, 1941, pp. 504–505; Stoddard, Tyznik, and Allen, Wis. Bul. 480; Wis. Bul. 510.

130. Hayden, Monroe, and Perkins, Ohio Bul. 502; Olson, S.D. Bul. 252.

131. Fat percentages, except for Brown Swiss and Shorthorn milk, from Dairy-Herd-Improvement Association records tabulated by Nystrom, U.S.D.A. Farmers' Bul. 1443, Rev. Ed., 1946; other data chiefly from Overman, Sanmann, and Wright, Ill. Bul. 325; Overman, Garrett, Wright, and Sanmann, Ill. Bul. 457; Overman, Keirs, and Craine, Ill. Bul. 567.

132. Holstein Herd Test News Letter, April, 1955.

133. Ellenberger, Newlander, and Jones, Vt. Bul. 556.

134. Dahlberg, Guthrie, Herrington, and Krukovsky, N.Y. (Cornell) Rpt. 1946.

135. Gowen, Milk Secretion; Graves and Fohrman, U.S.D.A. Bul. 1352; White and Judkins, Conn. (Storrs) Bul. 94; McCandlish, Iowa Res. Bul. 73; Headley, Nev. Bul. 131; Turner, Ragsdale, and Brody, Mo. Bul. 221; Brody, Mo. Res. Bul. 105; Dickerson and Chapman, Wis., Amer. Soc. Anim. Prod., Proc., 1939; Clark, Jour. Dairy Sci., 7, 1924, pp. 547–554; Hammond and Sanders, Jour. Agr. Sci., England, 13, 1923, pp. 74–119; White and Drakeley, Jour. Agr. Sci., England, 17, 1927, pp. 420–427; Glen and McCandish, Jour. Agr. Sci., England, 20, 1930, pp. 45–52; Sanders, Jour. Agr. Sci., England, 20, 1930, pp. 145–185.

136. Kendrick, U.S.D.A., BDI Inf. 162, 1953.

137. Voeller et al., Ohio, Jour. Dairy Sci., 36, 1953, pp. 584–585; Putnam, Bowling, and Conklin, West Va., Jour. Dairy Sci., 24, 1944, pp. 903–907.

138. Espe and Smith, Secretion of Milk, 4th Ed., pp. 159–162.

139. Ross and Winther, N.Y. (Cornell) Bul. 589.

140. Regan and Mead, Cal., Jour. Dairy Sci., 4, 1921, pp. 495–509; Fitch, Becker, and McGilliard, Kan., Jour. Dairy Sci., 5, 1922, pp. 259–271; Regan, N.J. Rpt. 1921; Penn. Buls. 176, 181; Wylie, Tenn., Jour. Dairy Sci., 6, 1923, pp. 292–298.

141. Gowen, Me., Jour. Agr. Res., 16, 1919, pp. 79–102; Eckles and Shaw, U.S.D.A., Bur. Anim. Indus., Bul. 157; Campbell, Jour. Dairy Res., England, 3, 1931, pp. 52–60; 4, 1932, pp. 28–36.

142. Koshi and Petersen, Minn., Jour. Dairy Sci., 37, 1954, p. 673; see also: Donker and Dalton, Ga., Jour. Dairy Sci., 38, 1955, p. 618.

143. Atkeson, Id. Bul. 164; Cash and Yapp, Ill., Jour. Dairy Sci., 33, 1950, p. 382; Lush and Schrode, Iowa, Jour. Dairy Sci., 33, 1950, pp. 338–357; Ragsdale, Turner, and Brody, Mo., Jour. Dairy Sci., 7, 1924, pp. 249–254; Dahlberg, N.Y., Hoard's Dairyman, 68, 1924, p. 436; Woodward, U.S.D.A. Cir. 180; Huynen, Proc. World's Dairy Cong., 1923; Copeland, Jour. Dairy Sci., 17, 1934, pp. 815–821.

144. Woll, Cal. Bul. 351; Beach, Conn. (Storrs) Bul. 29; Becker and Dix Arnold, Fla., Jour. Dairy Sci., 18, 1935, pp. 389–399; McCandlish, Iowa, Jour. Dairy Sci., 7, 1924, pp. 255–261; Pearl, Me. Sta., Rpt. of Prog. on Animal Husb. Inves. in 1915; Ragsdale, Turner, and Brody, Mo. Buls. 189, 197, and Jour. Dairy Sci., 6, 1923, pp. 527–531; Linfield, Utah Bul. 68; Woll, Wis. Bul. 116; Woll, Wis. Res. Bul. 26; Woodward, U.S.D.A., Jour. Dairy Sci., 28, 1945, pp. 209–218; Drakeley and White, Jour. Agr. Sci., England, 17, 1927, pp. 118–139.

145. Gaines and Davidson, Ill. Bul. 272; Hooper, Ky. Bul. 248; Ragsdale, Turner, and Brody, Mo., Jour. Dairy Sci., 7, 1924, pp. 24–30; Erb, Goodwin, Morrison, and Shaw, Wash., Jour. Dairy Sci., 35, 1952, pp. 224–233; Sanders, Jour. Agr. Sci., England, 17, 1927, pp. 502–523.

146. Whittlestone, New Zealand, Jour. Dairy Res., 21, 1954, p. 50.

147. Davis, Harland, Caster, and Kellner, Ariz., Jour. Dairy Sci., 30, 1947, pp. 415–433; Regan and Richardson, Cal., Jour. Dairy Sci., 21, 1938, pp. 73–79; White and Judkins, Conn. (Storrs) Bul. 94; Ga. Rpt. 1925; Becker and Dix Arnold, Fla., Jour. Dairy Sci., 18, 1935, pp. 389–399; Davidson, Ill. Rpt. 1926; Weaver and Mathews, Iowa Res. Bul. 107; Frye, Cannon, and Bird, Iowa, Jour. Dairy Sci., 33, 1950, pp. 257–266; Seath and McCullough, Ky., Jour. Dairy Sci., 34, 1951, pp. 501–502; Brooks, Mass. (Hatch) Rpt. 1895; Ragsdale, Turner, and Brody, Mo. Buls. 189, 197; Brody, Turner, and Hays, Mo. Bul. 236; Herman et al., Mo. Bul. 556; Cobble, Herman, and Ragsdale, Mo., Jour. Dairy Sci., 34, 1951, p. 501; Headley, Nev. Bul. 131; Hills, Vt. Rpt. 1907; Woodward, U.S.D.A., Jour. Dairy Sci., 6, 1923, pp. 466–478; Houston and Hale, Jour. Dairy Res., 3, 1932, pp. 294–309; Heinmann, Jour. Dairy Sci., 30, 1947, pp. 757–762.

148. Regan and Richardson, Cal., Jour. Dairy Sci., 22, 1938, pp. 73–79.

149. Gaalaas, U.S.D.A., Jour. Dairy Sci., 28, 1945, pp. 555–563.

150. Ga. Rpt. 1925.

151. Seath and Miller, La. Rpt. 1945.

152. Frick, Mann, and Johnson, Conn., Jour. Dairy Sci., 30, 1947, pp. 631–640; Gaines, Ill. Rpt. 1933; Cannon, Iowa, Jour. Dairy Sci., 16, 1933, pp. 11–15; Morrow, Keener, and Hall, N.H. Tech. Bul. 86; Morrow, N.H. Bul. 402; N.J. Rpt. 1945; Bierly, N.Y. (Cornell) Bul. 804; Oloufa and Jones, Ore., Jour. Dairy Sci., 31, 1948, pp. 1029–1031; Woodward, U.S.D.A., Jour.

Dairy Sci., 28, 1945, pp. 209–218; McDowell, U.S.D.A. Farmers' Bul. 1604.
153. Eckles, Mo. Bul. 100; Woll, Wis. Rpts. 1902, 1903.
154. Eckles and Palmer, Mo. Res. Bul. 25.
155. Ragsdale and Swett, Mo. Bul. 179.
156. Riddet, Campbell, McDowall, and Cox, New Zealand Jour. Sci. and Technol., 23, 1941, No. 2A, pp. 80A–112A; Rowland, Nat. Inst. for Res. in Dairying, England, report at European Nutr. Conference, July, 1946.
157. N.Y. (Geneva) Rpt. 1940.
158. Gowen and Tobey, Me. Bul. 360; Overman and Wright, Jour. Agr. Res., 35, 1927, pp. 637–644.
159. Eckles and Palmer, Mo. Res. Bul. 24.
160. Davis and Harland, Ariz., Jour. Dairy Sci., 29, 1946, pp. 839–844; Ariz. Rpt. 1944; Nevens, Alleman, and Peck, Ill., Jour. Dairy Sci., 9, 1926, pp. 307–345; McCandlish, Iowa, Jour. Dairy Sci., 4, 1921, pp. 301–320; Lindsey, Mass. Rpt. 1908; Allen, Minn., Jour. Dairy Sci., 17, 1934, pp. 379–395; Allen and Fitch, Minn., Jour. Dairy Sci., 24, 1941, pp. 516–517; Petersen, Minn., Jour. Dairy Sci., 10, 1927, pp. 70–82; Wing, N.Y. (Cornell) Bul. 92; Lucas and Loosli, N.Y., Jour. Anim. Sci., 3, 1944, pp. 3–11; Sutton, Brown, and Johnston, Ohio, Jour. Dairy Sci., 15, 1932, pp. 209–211; Olson, S.D. Rpt. 1923; Adams, and Allen, Wis., Jour. Dairy Sci., 35, 1952, pp. 1117–1120.
161. Woll, Cal. Bul. 335; Kendall and Engberson, Ill., Jour. Dairy Sci., 33, 1950, p. 388; Perkins, Bachtell and Weaver, Ohio Bul. 497; Frederiksen, Meddelelse fra Forsogs-laboratoriets Husdyrbrugsafdeling, Denmark, 1923, 1925, 1927.
162. Savage, Harrison, Maynard, and Work, N.Y. (Cornell) Rpt. 1936.
163. Perkins, Ohio Bul. 515.
164. Channon, Drummond, and Golding, Analyst, 49, 1924, pp. 311–327; Golding and Zilva, Biochem. Jour., 22, 1928, pp. 173–182; Hart, Hadley, and Humphrey, Wis. Res. Bul. 112; Petersen, Minn., Jour. Dairy Sci., 15, 1932, pp. 283–286; McCay and Maynard, N.Y., Jour. Biol. Chem., 109, 1935, pp. 29–37; Maynard, McCay, Gardner, and Paul, N.Y. (Cornell) Rpt. 1938; Sutton and Hildreth, Ohio Bul. 579; Hart, Hadley, and Humphrey, Wis. Res. Bul. 112.
165. Dvorachek and Lippert, Ark. Buls. 221, 257; Richardson and Abbott, Cal. Rpt. 1930; Theophilus, Id. Buls. 221, 225; Overman and Garrett, Ill., Jour. Agr. Res., 45, 1932, pp. 51–58; Hunziker et al., Ind. Bul. 159; Cannon et al., Iowa Rpt. 1949; Frye, Cannon, and Bird, Iowa, Jour. Dairy Sci., 33, 1950, pp. 205–215, 257–266; Bartley et al., Iowa, Jour. Dairy Sci., 34, 1951, pp. 536–547; Lindsey, Mass. Rpt. 1908; Hill and Palmer, Minn., Jour. Dairy Sci., 21, 1938, pp. 529–544; Herrzen, Moore, and Cowsert, Miss. Tech. Bul. 25; Morse, N.H. Bul. 16; Gallup, Okla. Rpt. 1936–38; S.C. Rpt. 1929; S.D. Rpt. 1926; Hanson, Arbuckle, and Shepherdson, Texas Bul. 670; Texas Rpt. 1947–49; Brown, Dustman and Weakley, West Va., Jour. Dairy Sci., 24, 1941, pp. 265–275.
166. Wilster et al., Ore. Bul. 414.
167. Woodward, U.S.D.A., Jour. Dairy Sci., 6, 1923, pp. 466–478.
168. Linfield, Utah Bul. 68; Hills, Vt. Rpt. 1907; Humphrey and Woll, Wis. Bul. 217.
169. White, Johnson, Rettger, and McAlpine, Conn. (Storrs) Bul. 154; Ky. Rpt. 1937; Gow and Hamilton, Md. Bul. 387; Morgan and Davis, Nebr. Res. Bul. 46; Mohler, Wight, and Lash, U.S.D.A., Misc. Pub. 384.
170. Hooper and Bacon, Ky. Bul. 234; McCandlish, Iowa, Jour. Dairy Sci., 9, 1926, pp. 65–67; Copeland, Texas, Jour. Dairy Sci., 12, 1929, pp. 464–468; Erb, Goodwin, Morrison, and Shaw, Wash., Jour. Dairy Sci., 35, 1952, pp. 234–244.
171. Hills, Vt. Rpts. 1899, 1900; Jour. Landw., 41, 1893, p. 332.
172. White, Conn. (Storrs) Bul. 181; Woodward, Shepherd, and Graves, U.S.D.A., Misc. Pub. 179.
173. Woodward, Turner, and Curtice, U.S.D.A. Bul. 147.
174. Taylor and Anthony, Mich. Quar. Bul., 15, 1932, pp. 118–127.
175. Henderson, Penn. Rpt. 1916; McCandlish, Jour. Dairy Sci., 1, 1917–18, p. 475; Hays and Thomas, Jour. Agr. Res., 19, 1920, p. 123; Jack and Bechdel, Jour. Dairy Sci., 18, 1935, pp. 195–205.
176. For summaries on this subject, see Sommer, Market Milk and Related Products, 2nd Ed., 1946; Petersen, Dairy Science, 2nd Ed., 1950; Greenbank, U.S.D.A., Jour. Dairy Sci., 31, 1948, pp. 913–933; Krukovsky, N.Y., Jour. Dairy Sci., 35, 1952, pp. 21–29; Stull, Ariz., Jour. Dairy Sci., 36, 1953, pp. 1153–1164; Guthrie, N.Y. (Cornell) Memoir 340.
177. Krukovsky, Loosli, and Whiting, N.Y., Jour. Dairy Sci., 32, 1949, pp. 196–201; Krukovsky, N.Y., Jour. Dairy Sci., 35, 1952, p. 481; Krukovsky et al., N.Y., Jour. Dairy Sci., 37, 1954, pp. 1–9.

CHAPTER XXVI

FEEDING AND CARING FOR DAIRY COWS

I. Feeding for Milk Production

1068. Essentials in feeding and care.—The net return a dairyman receives from his dairy business depends equally on the productive capacity of his cows and on the feed and care he gives them. Just as necessary as well-bred cows, capable of high yields, are efficient rations and intelligent care. Without these, good cows are forced to become poor and unprofitable producers.

The chief essentials in the proper feeding and care of dairy cows are:

1. The use throughout the year of economical, well-balanced rations, which provide the nutritive requirements that have been discussed in the previous chapter.
2. Adjusting the amount of concentrates for each cow to her actual production.
3. Palatable rations, containing a reasonable variety of feeds.
4. Rations that are slightly laxative, instead of constipating.
5. An abundance of good roughage, and some succulent feed, except when succulent feeds are unduly expensive.
6. Plenty of good water, conveniently accessible.
7. Dry periods of proper length.
8. Comfortable surroundings, both in winter and during the pasture season.
9. Regularity in feed and care.
10. Kindness on the part of the herdsman.

Neglect of these simple essentials will seriously reduce the net income from the dairy herd.

Commonly, dairy cows are fed roughage—hay or hay and silage—twice a day and concentrate or grain mixture at or before milking.

1069. Cows should be fed individually.—To secure good net returns from a dairy herd, it is necessary to feed each cow according to her actual yield of milk and fat. A high-producing cow needs a much greater amount of total digestible nutrients than a low producer. Since she cannot eat much more hay or other roughage than a low producer, she must be fed a liberal amount of grain or other concentrates. Otherwise, her milk yield will soon fall to the level that is permitted by the amount of nutrients she actually receives.

In spite of the great difference in the real needs of the various cows in a herd, many dairymen make the mistake of feeding all their cows the same amount of concentrate or grain mixture, regardless of their actual yields. This practice seriously underfeeds the high producers and therefore reduces the net returns from the herd. It just as seriously overfeeds the poor cows. They are unable to convert the excess nutrients into milk, but instead turn them into body fat or waste them entirely.

The amount of grain mixture needed by a cow depends not only on her yield of milk and fat but also on the amount and quality of the roughage she eats. The simplest way of finding the number of pounds of grain mixture that should be fed to each cow per day is to use the grain feeding tables given in Appendix Table VIII. These tables, which have been discussed in the previous chapter, show at a glance the amounts of grain mixture needed by cows producing various amounts of milk of any fat content when they are fed different amounts of roughage, or when on excellent, good, or fair pasture.

It has been emphasized in the previous chapter that the most profitable level of concentrate feeding will depend on the local conditions, especially on the relative cost of concentrates and rough-

ages, on the price of milk, and on the quality and abundance of roughage. (**1022–1028**) As there pointed out, under certain conditions the greatest net return may be secured, even from good cows, when they are fed an abundance of high-quality roughage with little or no concentrates. On the other hand, when milk is high in price in comparison with the cost of concentrates, it may be most profitable to feed larger allowances of concentrates, or grain mixture, than stated in the grain feeding tables.

GOOD COWS NEED BETTER ROUGHAGE

A limited amount of dry corn stover or corn fodder can be fed satisfactorily to dairy cows, along with better roughages, such as legume hay and silage. However, corn stover or corn fodder is not efficient as the only roughage.

As pointed out in the preceding chapter, self-feeding dairy cows is ordinarily not desirable. (**1032**)

1070. Palatable rations.—Both the roughages and the concentrate mixture for cows producing a good yield of milk should be as palatable as possible. If the roughage is not palatable, the cows will eat much less of it than they would of well-liked roughage, and it will be necessary to feed them an unusually large amount of concentrates.

Such roughages as corn stover, grass hay cut at the usual stage of maturity, and even straw can be fed to dairy cows in limited amounts, along with better roughage. However, for the best results they should not form the chief roughage for good cows. It is preferable to feed two kinds of roughage to dairy cows, for when fed even good alfalfa hay continually as the only roughage, they show a keen desire for other roughage in addition, and seem to thrive better when receiving it.

It is usually easy to provide a palatable concentrate mixture, or "grain mixture," for dairy cows, for they like most all the common grains and byproduct concentrates, if the feeds are of ordinary quality. Sometimes it is economical to include in the grain mixture a feed like malt sprouts or rye feed, which is not itself palatable. This may be done without making the whole mixture unpalatable, if only a reasonable amount is mixed with well-liked feeds, such as ground corn, ground oats, wheat bran, linseed meal, molasses, etc.

1071. Variety.—There is considerable difference of opinion concerning the

need of "variety," or of several different ingredients in a concentrate mixture for dairy cows.

When cows of ordinary productive capacity have good roughage, including a reasonable amount of legume hay, it is not necessary to go to extra expense to use a concentrate mixture which has several ingredients. For example, it has been shown in the previous chapter that if cows have plenty of alfalfa hay and corn silage for roughage, or if they are fed alfalfa hay as the only roughage, good production can be secured when they receive in addition such a simple grain mixture as one-half ground corn and one-half ground oats. (**1016**)

The palatability and nutritive merits of the individual feeds in a concentrate mixture are of greater importance than the number of ingredients. A concentrate mixture containing a reasonable variety of well-liked ingredients is, however, apt to be more palatable than a simple combination, such as a mixture of grains, or of grains and a single protein supplement. Many dairy experts therefore advise that for high-producing cows, especially those on official test, the concentrate mixture should contain 5 or 6 ingredients.

Several experiments have been conducted to compare such a simple concentrate mixture as ground corn or corn and oats, supplemented by soybean oil meal or cottonseed meal, with a mixture having much greater variety and usually having more bulk.[1] When the protein content of the mixtures has been equal, there has been no appreciable difference in the yield of milk or fat, or in the effect on the live weights of the cows. These experiments have been conducted with cows fed good roughage, such as well-cured hay and silage, or with cows on pasture. It is barely possible that with poor-quality roughage there might be an advantage from a concentrate mixture containing a greater variety of feeds.

It has previously been shown that the kind or quality of protein in rations for dairy cows is of little importance when the rations contain good roughage and are made up of feeds that are otherwise satisfactory. (**1018**) In New York experiments there was also no difference in the results from a concentrate mixture made up largely of home-grown grains and one made up chiefly of by-product feeds.[2]

If a satisfactory ration is being fed, there is no advantage in changing it from time to time, in order to supply additional variety. While humans would tire of a monotonous diet, stock fortunately do not have such fickle appetites.

If cows accustomed to a good grain mixture are changed to another equally good, but having a decidedly different taste, they may at first not like the new mixture. However, in nearly all cases they will soon become used to it. When cows which have been on advanced registry test and have had their whims for special feeds indulged by expert herdsmen are returned to the regular herd, it often takes them some time to become accustomed to the less-luxurious manner of life.

1072. Bulkiness of concentrate mixture.—It is a common belief that when high-producing cows are fed a liberal amount of concentrates, there will be less tendency for them to go off feed if some bulky feeds, such as wheat bran, ground oats, or dried beet pulp, are included in the mixture. Many experienced dairymen prefer a concentrate or grain mixture which does not weigh more than about 1 lb. to a quart.

For cows fed the usual amount of grain mixture, if it is cheapest to feed a heavy mixture that contains no bulky feeds, the mixture may readily be distributed over silage after the latter has been placed in the mangers. This will insure adequate mixing of the concentrates and silage in the digestive tract. On the other hand, it is wise to use only a bulky concentrate mixture for cows that are fed very liberal amounts of concentrates, such as cows on advanced registry test.

In the previous discussion on "variety" it has been shown that with good roughage just as satisfactory results have been secured from such a mixture as ground corn and soybean oil meal or

cottonseed meal, as from a mixture having much more variety and containing bulky concentrates.

In Illinois and Michigan tests heavy concentrates, such as ground corn and linseed meal, were fed to cows separately from the roughage, and the cows were slaughtered soon afterwards.[3] It was found that most of the concentrate was well-mixed with the previous contents of the rumen and the honeycomb, and only a small part was in the form of separate lumps or boluses. In the Michigan experiments a concentrate mixture of only ground corn and linseed meal was satisfactory for feeding dairy cows, even when it was fed separately from the roughage.

Though many dairymen prefer a concentrate mixture that has a coarse texture, experiments have shown no advantage for such a mixture over an ordinary ground mixture made of the same feeds. (**1052**)

1073. Rations that are slightly laxative.—In order to secure the most efficient production, dairy cows should receive rations that are slightly laxative. This is readily accomplished when plenty of well-cured legume hay or good silage is fed. If all the roughage is of a rather constipating nature, such as ordinary grass hay, corn stover, or straw, care should be taken to include in the grain mixture a sufficient amount of laxative feeds, such as wheat bran, linseed meal, or molasses, to counteract the constipating effect of the roughage.

1074. An abundance of good roughage.—The importance of an abundance of good roughage has been fully discussed in the preceding chapter. (**1022–1029**) The results from supplying plenty of high-quality roughage are well shown by a recent cost study on Michigan farms.[4] On the farms where abundant excellent roughage was provided, the average milk yield per cow was 12,043 lbs., and 2,614 lbs. of grain and only 189 lbs. of protein supplements were fed. Where the roughage supply was poor, good production was also secured (an average of 11,727 lbs.), but it was obtained by feeding much more grain and protein supplements (3,921 lbs. grain and 519 lbs. protein supplements). With the excellent roughage supply, the feed cost per 100 lbs. milk was 46 cents less and the net return per cow $65 more than with poor roughage.

In most of our dairy districts it is economy to supply dairy cows with an abundance of good hay during the barn-feeding season. The only usual exception is where the weather is such that it is very difficult to make satisfactory hay. Under these conditions cows should be filled up with good silage, but a small amount of hay should be fed in addition, if possible.

If cows are fed all the well-cured hay and other good roughage that they will eat, considerably less concentrates are needed to keep up a high milk yield than when the supply of roughage is scanty or of poor quality. (**1022**) If one has plenty of hay, it is an excellent plan to feed it so liberally to good cows that they leave some of the coarser stems. These less nutritious parts can be used for bedding or fed to idle work stock. When fresh hay is put before cows more often than twice a day, the amount they will eat is generally increased somewhat.

The values of the various kinds of hay have been discussed in detail in the chapters of Part II. Where possible, legume hay or mixed legume-and-grass hay should be fed to dairy cows, as it is much richer in protein, calcium, and vitamins than the usual quality of grass hay. However, timothy or other grass hay is satisfactory for cows, if it is grown on well-fertilized land, and if it is cut early and well-cured. (**564**) When but little legume forage is fed, the concentrate mixture must, of course, be considerably richer in protein than is needed with an abundance of legumes in the ration. (**1016**)

1075. Succulent feeds.—Succulent feeds, such as silage, are highly desirable for dairy cows, because of the advantages that have been discussed in previous chapters. (**421, 523**) Such feeds are so palatable that when they are included in the ration cows eat more total roughage, and therefore need less concentrates than

when given only dry roughage. Also, because of the cooling and slightly laxative effect, silage and other succulent feeds aid in keeping high-producing cows thrifty. There is especial need of succulent feeds when there is little or no legume hay in the ration.

In this country silage is the common succulent feed for winter feeding. Though roots are an excellent feed for dairy cows, they are so much less economical than silage under our conditions that but few roots are grown for stock feeding. (**627**, **630**) Detailed information on the value of the various kinds of silage for dairy cattle has been given in earlier chapters. In our chief dairy districts corn is the most important silage crop, and in the plains states silage from the sorghums is of similar importance. Silage from alfalfa and other hay crops is excellent for dairy cattle when properly preserved. Such hay-crop silage is even higher than corn silage in carotene, and helps maintain a high vitamin A value in the milk throughout the winter. (**438**)

While silage is highly desirable for dairy cows during the winter, it is not absolutely necessary for good production. If cows are fed a liberal amount of excellent legume or mixed hay and are supplied with water in drinking cups, they may produce nearly as much milk as when they are fed silage in addition. However, unless the dry roughage is excellent, their production will be decidedly greater if they receive succulent feeds. (**503–504**)

Whether or not to supply silage is primarily a question of farm economics and farm management. (**424**) For example, in the corn belt the use of corn silage is generally advisable, on account of its high value and its economy. On the other hand, in certain of the western alfalfa districts nutrients can be provided so much more cheaply in alfalfa hay than in any form of silage that it may not be profitable to use silage.

1076. Amount of silage for dairy cows.—The amount of silage fed per head daily to dairy cows usually ranges from 20 to 40 lbs. per 1,000 lbs. live weight. When cows are fed twice a day all the silage and good legume hay that they will eat, they take about 3 lbs. of silage and 1 lb. of hay daily per 100 lbs. live weight, in addition to the usual amount of concentrate mixture. If the hay is of excellent quality, they may eat a little more hay than this.

Most dairymen who have plenty of both silage and hay let their cows have all of each that they will clean up, except perhaps in the case of cows on official test. Limiting the amount of silage and hay for such cows may induce them to eat more of the concentrate mixture.

Practically all of the advantage from feeding silage to cows can be gained when no more than 15 to 20 lbs. per head daily is fed, along with a very liberal amount of hay.[5] Where the cost of nutrients in silage is relatively high compared with the cost in hay, it may therefore be most economical to give the cows all the hay they will take and only half the usual amount of silage. If the hay is of especially good quality, they may consume even more dry matter and total digestible nutrients in roughage when thus fed than if given more silage. They will then need less concentrates to keep up a good yield of milk.

On the other hand, in sections where the weather makes the curing of hay difficult, it may be desirable to use silage as the only roughage, or to feed only a small amount of hay with all the silage the cows will eat. It should be borne in mind, however, that ordinarily the easiest way to provide ample amounts of vitamin D in winter rations is through feeding well-cured legume or mixed hay. (**1046**)

If corn or sorghum silage is fed as the only roughage or with but little hay, it is important to see that the concentrate mixture has plenty of protein to balance the low-protein silage. Also, it is wise to feed a calcium supplement to make sure there is plenty of this mineral nutrient. Cows fed silage as the only roughage will often eat 6 lbs. or more of silage daily per 100 lbs. live weight.

In some experiments the results have been very satisfactory when corn

or other silage has been fed as the only roughage, except for straw the cows may have picked up from the bedding.[6] For example, in an Iowa experiment heifers were paired at birth, and one heifer in each pair was fed corn silage as the only roughage for consecutive years.[7] The other heifer in each pair had hay for the first 6 months and then both hay and silage. All were on pasture in summer after a year of age. The calves having silage as the only roughage did not grow quite so rapidly at first, but by a year of age there was no appreciable difference in size. In 2 lactations the silage-fed cows produced even more milk and fat than those receiving both hay and silage.

Differing from these results, in other experiments it has been necessary to feed a greater amount of concentrates than usual to keep up the milk yield when corn silage or hay-crop silage was the only roughage; or else the milk production has been lowered.[8] Considering all the information available, it seems wise under usual conditions to feed at least 6 or 7 lbs. per head daily of good hay in addition to silage, instead of using silage as the only roughage.

II. Feeding Cows on Pasture

1077. Good pasture necessary for cheap milk production.—No factor is of greater importance in reducing the cost of milk production than providing excellent pasture for the herd over just as long a period as possible. First-class pasture is highly palatable and also very nutritious. As a result, when cows can eat their fill of it, they will get from the pasture forage a decidedly larger proportion of the nutrients they need for high milk production, than when barn-fed on good hay and silage. Good pasture is high in digestible nutrients on the dry basis, and it is also rich in protein, minerals, and vitamins. (358–362)

Unfortunately, in most sections permanent pastures furnish ideal pasturage for only a short season, and in midsummer they are too often parched and brown. The importance of pasture fertilization and the methods by which good pasture can be provided throughout the entire season are discussed in detail in Chapter XIII.

The great economy of providing good pasture for dairy cows has previously been emphasized in Chapter XIII. (357) When well-fertilized and properly-managed pastures are provided, a high yield of milk can be maintained throughout the summer with a minimum amount of grain or other harvested feed. On the other hand, when little effort is made to improve the pastures, a large amount of additional feed must be supplied in order to keep up a good milk flow and to prevent the cows from running down in flesh.

Pasture the Cheapest Feed

An abundance of good pasture is necessary for economical milk production, because such pasture supplies the cheapest feed. (From New York State College of Agriculture, Cornell University.)

The proper feeding of milk cows on pasture is much simpler than is winter feeding, and doubtless this is why so many farmers, busy with their crops, fail to give their herd the necessary attention in summer. Often the cows are merely turned to pasture after milking at night and in the morning, with no further thought as to the supply of feed actually available. It is then no wonder that when the pasturage becomes scanty in midsummer, the cows run down in flesh and fall off severely in yield of milk.

A shortage of feed in midsummer is much more serious for dairy cows than for beef cattle being fattened on pasture. When the pasture becomes scanty, the beef cattle may not much more than maintain their weights, but when the

pasture springs up again after the fall rains, they will make good gains. On the other hand, if the milk yield of high-producing cows is seriously reduced by scanty feed, it is difficult or impossible to bring them back to their former yield by liberal feeding in the fall. Also, succulent, palatable pasturage is more important for dairy cows than for beef cattle.

Care should be taken to provide good pasture for cows at night. In Virginia studies it was found that cows did half of their grazing at night.[9]

In the spring many dairymen make the mistake of turning the herd to pasture before the grass is well started. This not only injures the pasture but also is apt to decrease the yield of milk, for the cows cannot get much nourishment from the scanty forage. It is important, however, that grazing start as soon as the grass is ready. Otherwise, the cattle may be unable to keep the forage grazed down during the period of most rapid growth, and it will then become too mature and will be unpalatable.

When cows in milk are first turned on pasture in the spring, the feeding of some concentrates and also hay should be continued until they become used to pasture and until the grass becomes abundant. If this is not done, good cows will run down in condition. The young grass stimulates them to produce more milk than on their winter ration, but it is frequently so low in dry matter and nutrients that the cows are unable to eat enough of it to meet their needs.

Often cows are left on pasture, without other roughage, entirely too late in the fall. They should be housed in the barn and be on full winter rations before poor pasture or unfavorable weather cuts down their yield. Much of the drop in milk yield that often occurs in the fall can be prevented if the cows are changed gradually from pasture to barn-feeding conditions. During this change plenty of good hay should be fed and also silage, if available. By starting the feeding immediately after silo filling, top spoilage may be entirely avoided.

1078. Pastures for dairy cows.—The value of the various pasture crops is discussed in detail in Chapters XVI and XVIII. Throughout the northern states, bluegrass and combinations of bluegrass with white clover and other legumes are the most common permanent pastures. In the central states and southward, combinations of grasses and lespedeza provide excellent pasture throughout the growing season. In the South, Bermuda grass and other southern grasses take the place of the bluegrass of the North.

Pasture mixtures grown in the regular crop rotation, such as a mixture of alfalfa and brome grass or orchard grass or a combination of Ladino clover and grass, provide a much greater yield than permanent bluegrass pasture. Still more important is the fact that they furnish good feed in midsummer, when bluegrass is often parched and brown.

In the South good pasture can be provided during most of the winter by winter cereal pasture or else winter legumes or legume-and-cereal combinations. Such pasturage will increase the winter milk yield and make a decided decrease in the cost of production.[10] Even in the northern states winter grain provides excellent late fall and early spring pasture.

The carrying capacity of pastures varies widely, depending on the soil and climate and especially on how wisely the pasture is managed. If no supplemental feed is provided for periods of drouth, 1.5 to 2.5 acres of fairly good pasture should be provided per cow, but if such additional feed is furnished and the pasture is properly fertilized, the pasture allowance can be reduced to 1 acre per cow or even less. In the West, irrigated pasture which is well fertilized may carry more than 2 cows per acre throughout the season.

Cows on abundant pasture will eat 90 to 150 lbs. of forage a day, and sometimes 200 lbs. or more. To harvest this amount of grass with her mouth, a cow must graze several hours a day, even when the pasture is good. When the forage is scanty, she spends much more energy in grazing in an effort to get enough feed. In Kansas tests, cows spent 7.3 hours a day grazing on poor pasture,

while they needed to graze only 5.6 hours on good pasture.[11]

1079. Supplementing scanty pasture.—The various methods of supplementing permanent pasture in midsummer are discussed in Chapter XIII. Often the best way is to use for pasture at this season the second crop on a mixed legume-and-grass hay field which has been cut early. Another method is to grow Sudan grass or some other annual pasture crop for summer pasture.

If plenty of forage cannot be provided throughout the summer by one of these means, the cows should be fed silage, hay, or green soiling crops to make up the lack. This is generally much more economical than to try to keep up the production by merely increasing the amount of concentrates. When there are enough cows in the herd to use up silage fast enough to keep it from spoiling, silage is generally a much more economical summer feed than soiling crops. (386)

If soiling crops are used, it should be borne in mind that they are more watery than good corn silage, and hence it is necessary to feed a considerably greater weight.

1080. Feeding cows on pasture.—It is often difficult to decide how much grain mixture to feed cows on good pasture, or whether to feed no grain at all. The answer depends on the amount and quality of the forage the pasture furnishes and on the actual production of the cows.

Good pasture alone will provide cows with sufficient nutrients for body maintenance and the production of about 10 to 20 lbs. of milk, depending on its richness. If the pasture is excellent, it will provide for still more milk. Cows of high productive capacity that are fed no grain mixture on pasture may continue to yield more milk than these amounts, but they must draw on their bodies for the additional nutrients needed. Consequently, they will lose weight and run down in condition.

The "Grain feeding table for cows on pasture" in Appendix Table VIII provides a convenient guide for the feeding of grain or other concentrates to cows on various grades of pasture. Separate recommendations are made for cows on excellent, good, and fair pasture, and for specific yields of milk containing various percentages of fat. These recommendations are based upon the results of the various studies that have been made of the feed requirements of cows on pasture.[12]

Good cows should be fed about the amounts of grain mixtures shown in this table, except when milk is unusually low in price compared with the price of grain and other concentrates. It may then be most economical to feed no grain to cows on good pasture unless they are producing more than 1 lb. of butterfat a day, and to feed higher producers only one-half to two-thirds as much as stated in the table.

Even when the feeding of a grain mixture to cows on good pasture does not result in enough higher production during the summer to show an immediate profit, it may nevertheless be advisable. This is because it will prevent good cows from running down in condition on pasture and will result in higher yields during the following fall and winter.

If cows have an abundance of good forage on pasture, the feeding of hay in addition does not usually increase milk production enough to be profitable.[13] However, on such legume pasture as alfalfa or Ladino clover, providing hay in a rack on pasture may help prevent bloat. (49)

Since young grass and other forage plants are very rich in protein, on the dry basis, there is no need of using a grain mixture that is rich in protein for cows on good pasture. (359) Merely a mixture of farm grains or a concentrate mixture containing 12 per cent protein will provide plenty of protein for cows on excellent pasture, except in the case of unusually heavy producers. This is shown clearly by the results of Michigan and Ohio experiments.[14] In these tests cows on good pasture produced as much or nearly as much milk when fed a concentrate mixture having only 11 to 12 per cent total protein or only a mixture of

grain as others fed a mixture containing much more protein. In no case was the yield on the high-protein mixture enough greater to pay for the additional cost.

Unless the grass is kept growing actively by liberal fertilization and proper pasture management, it will be considerably lower in protein, on the dry basis, during midsummer. It will then be necessary to increase the protein content of the concentrate mixture. Unless the pasture is decidedly poor, however, it will not be necessary to have more than 16 to 18 per cent protein in the mixture.

Various concentrate mixtures suitable for feeding on excellent, good, fair, and poor pasture are given in Appendix Table VII.

III. Feed and Care Before and After Calving

1081. Dry period important.—Dairy cows should have a dry period for a time before calving, as they will then produce considerably more milk in a year than if they are milked continuously.[15]

The rest period enables the cow to rebuild in her body the store of nutrients which she has drawn upon during the height of milk production. Also, a dry period is necessary for proper recuperation and development of the secreting tissues of the mammary gland before another lactation starts. (298) It has been shown in the previous chapter that only during the dry period and the last weeks of lactation can a high-producing cow regain the calcium and phosphorus drawn from her body stores earlier in lactation. (1038) For this reason alone, it is undoubtedly important that good cows have a dry period of reasonable length.

The length of dry period needed depends on the productive level of the cow and on her state of flesh at the end of lactation. High producers should have a longer rest than lower yielders, and cows thin in flesh should be dry long enough and be fed so that they will be in good condition by calving time.

Dairy scientists differ in the length of dry period advised. Some recommend that a good cow should be dry 8 weeks, while others advise a dry period of 30 to 60 days, depending on how much milk the cow has produced and her state of flesh.

From a study of records of cows in dairy herd-improvement associations in 12 states, Klein and Woodward of the United States Department of Agriculture concluded that a dry period of about 8 weeks gave the best annual yield for cows producing 10,000 lbs. of 4 per cent milk a year and calving at 12-month intervals.[16] Either a longer or a shorter dry period reduced the annual milk yield.

Various methods are used in drying off persistent producers. Probably the best and most rapid method is to discontinue milking abruptly, if the cow is not giving more than about 20 lbs. of milk a day.[17] If a cow is giving more milk than this, her production can usually be reduced to this level by severely restricting her feed.

After the last milking, it is best to wash and dry the teats carefully and then to seal the ends with collodion to prevent the entrance of bacteria. If the udder fills so much with milk that there is danger of its becoming congested, the cow should be milked out clean, and only milked again as it may be necessary. This method dries off a cow much more rapidly than the older method of gradually decreasing the frequency of milking, first to once a day, then once in 2 days, etc. This method should not, however, be used for cows having mastitis.

1082. Feed and care during dry period.—Proper feeding during the dry period is important to get the cow into condition for heavy production and also to prevent trouble at calving time. During the barn-feeding season no better ration can be provided than legume hay and silage, with enough grain mixture to get the cow into proper condition before she freshens. Plenty of well-cured hay is important, because it furnishes vitamin D. This is necessary for the rebuilding of the stores of calcium and phosphorus in the bones, which may have been lost during the flush of milk production.

When dry cows are fed legume hay as the only roughage, a mixture of farm grains alone, such as one-half ground

corn or barley (by weight) and one-half ground oats, will provide sufficient protein. It has been the belief of some that the feeding of a concentrate mixture consisting largely of corn to a cow during the dry period would increase the congestion in the udder at calving time. However, in a Kansas test the feeding of corn as the only concentrate during the dry period did not produce any significant difference in the results.[18]

If at least one-third of the roughage, on the dry basis, is legume forage, the grain mixture need not have more than 12 per cent protein. However, if the cows must be fed only low-protein roughage, the grain mixture should have at least 16 per cent protein. Unless the grain mixture contains 20 per cent or more of feeds high in phosphorus, such as wheat bran, linseed meal, or cottonseed meal, 1 lb. of bone meal or other safe phosphorus supplement should be added to each 100 lbs.

Formulas for several grain mixtures that are suitable for feeding with various kinds of roughage are given in Appendix Table VII. A popular mixture for dry cows that are fed little or no legume roughage is 100 lbs. of ground corn, hominy feed, or ground barley; 100 lbs. of ground oats; 100 lbs. of wheat bran; and 50 to 100 lbs. of linseed meal.

If a cow is in fairly good condition when she is dried off, 2 to 4 lbs. of grain mixture a day with good roughage should be sufficient. On the other hand, if she is thin, the amount should be increased to 5 or 6 lbs., or even more. Cows that are to be on advanced registry test are usually fed with great liberality when dry, so they will be fat at time of freshening. (**1103**)

During the pasture season, no additional feed need be furnished dry cows if there is plenty of forage. However, if pastures become scanty, enough additional feed should be fed to get them in the desired condition.

The benefit from getting cows into proper condition by calving time is shown by a New York trial.[19] Good cows which were fed well in the dry period produced an average of 705 lbs. more milk and 23 lbs. more fat than they had yielded in the previous lactation when they had been fed less liberally during the dry period. The previous year they had averaged 112 lbs. lighter in live weight at calving time. The increase in yield was secured by feeding only about 440 lbs. more concentrates during the dry period and during lactation. For each additional 100 lbs. of milk, only 62 lbs. of concentrates were fed, with no additional roughage. Except when milk is very cheap in comparison with the price of concentrates, this would make it decidedly profitable to feed sufficient concentrates during the dry period to get such cows into fairly good condition before calving.

Experiments by the United States Department of Agriculture show that except when cows are to be on official test, or when the price of milk is high compared with the price of concentrates, it does not pay to feed them so liberally during the dry period that they become very fat.[20]

In England the liberal feeding of cows during the dry period is called "steaming them up." Hammond of Cambridge University believes that good feeding for 6 weeks or so before calving is necessary to secure full development of the secreting cells of the mammary gland.[21]

However, it appears that the important point is to have the cows in good condition by calving time, regardless of the method of feeding used. In an Illinois trial cows and heifers fed only ample good roughage before calving produced about as much milk as others "steamed up" by feeding increasing amounts (up to 12 lbs. a day) of concentrate mixture during 6 weeks previous to calving.[22]

In the Tennessee Station herd excellent results have been secured by feeding the cows during the latter months of lactation enough concentrate mixture to get them into good condition by the time they are dried off.[23] During the dry period they are fed only plenty of good roughage. About the same total amount of concentrates is fed in a year as in the usual method. It is reported that with

this method there are fewer difficulties at calving time and less inflammation of the udder. This method is advisable only where cows can be fed abundant roughage of first-class quality.

It is often recommended that for a week or so before calving, a grain mixture should be fed which is very bulky and laxative, such as: (1) Equal parts by weight of ground oats and wheat bran; or (2) equal parts by weight of ground oats, wheat bran, and linseed meal. There is, however, no need of feeding a special mixture, if the ration previously fed has been laxative enough to prevent constipation. The recommendation is also often made that the allowance of concentrates be reduced at this time to only 3 or 4 lbs. a day, if more has been fed. Unless the cow's udder shows a tendency to become congested, it is not, however, necessary to reduce the allowance.

A cow that is soon to calve should be turned out for exercise each day when the weather is suitable. She must not be chased by dogs or be crowded through narrow doors or gates. Care should also be taken that she is not injured by slipping on the stable floor or on ice.

1083. Gestation period; frequency of calving.—In a study of the gestation periods of dairy cows of the various breeds, the United States Department of Agriculture found the average lengths in days for normal calving to be: Holsteins, 278.9; Jerseys, 279.3; Ayrshires, 278.7; Guernseys, 284.0; and Brown Swiss, 290.0.[24] Male calves are usually carried a trifle longer than heifers, and twins a shorter time than single calves. First gestation periods are commonly 1 to 2 days shorter than the average for all ages.

Unless dairymen wish to change the period of freshening in their herds, they usually prefer to have the cows calve at intervals of about 12 months, as this results in the highest annual yield per cow over a period of years. However, the average interval will generally be considerably longer than this, because of difficulty in getting some cows in calf. A much shorter interval than a year is apt to reduce the annual yield, especially in the case of high-producing cows.

When a cow is to be run on advanced registry test the next year, sometimes breeding is delayed a few weeks, as this tends to cause a higher yield in the following lactation period.

1084. Calving time.—Unless the herd is at pasture, the cow should be put in a thoroughly cleaned and disinfected box stall at least 2 or 3 days before the expected date of calving. Even when the cows are on pasture, it is wise to put a cow that is soon to calve in a box stall or in a small pasture lot where she can be given any needed attention.

As calving time approaches, the udder of a good cow will become swollen with milk, and in some cases may become decidedly congested. Some dairymen start milking such cows a few days before calving (called prepartum milking), in the belief that it will reduce the swelling and congestion. However, in experiments in which prepartum milking has been tested, in most cases it did not have this effect.[25] In these experiments prepartum milking did not generally increase the milk yield in the following lactation.

When a cow is milked prepartum, it is necessary to save for the calf, by freezing or refrigeration, the colostrum milk that will be produced mostly before the calf arrives, or else to feed it colostrum from another cow, or to feed it a vitamin A supplement. (1117) If the udder becomes unduly congested, it is well to rub it twice a day with a mixture of one-half cod-liver oil and one-half ethyl alcohol, or some other suitable mixture.

The cow may be allowed feed and water as usual up to calving time, but she will not generally have much appetite soon before calving. She should not be molested during calving, unless assistance is needed. To avoid injuring her, assistance should then be given only by a veterinarian or some other experienced person. During and after calving, the cow should be protected from drafts.

As soon as the calf arrives, it should be given any needed attention. If it does

not begin to breathe promptly after birth, any mucus or membrane should be removed from its nostrils, and attempts should be made to start respiration by slapping the chest vigorously or by alternately compressing and relaxing it.

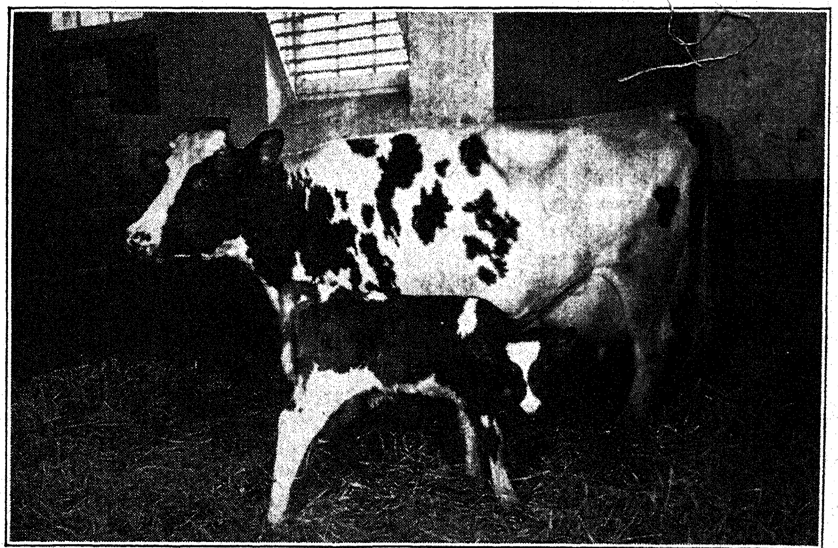
If the cow does not dry the calf by licking, it should be dried by rubbing with a cloth or dry straw. If the afterbirth is not expelled naturally within about 48 hours after the birth of the calf, the services of a veterinarian should be secured, if possible. The cow should not be allowed to eat the afterbirth.

If the calf is weak and does not nurse within a half hour, it should be helped to get its first meal. It is very important that the calf receive the colostrum. (270) To guard against navel infection, the navel should be disinfected with tincture of iodine soon after birth.

It is best to separate the calf from the cow not later than 24 hours after birth.[26] If left with her longer, it may get so much milk that scours will result. It is also usually less difficult to teach a calf to drink from a pail when it is separated from its dam not more than a day after birth, than when it remains with her longer.

1085. Feed and care after calving.—It is highly important that a cow be properly fed and cared for during the first month after calving. Because of her weakened condition, she should be blanketed after she calves, if the stall is too cold. The amount of feed should be very limited for the first day, and the cow should be given lukewarm water to drink, unless there is a drinking bowl in the stall. During the first day after calving she may be given what hay and other roughage (including silage) that she cares for, but she should have only a small amount of grain mixture. If the cow is doing well, she may have for the first feed about 1 lb. of the same concentrate mixture that was fed during the dry period. Some dairymen prefer to feed a cow a hot bran mash or a mash of bran and oats, fed as a slop, soon after calving.

After the first day, the amount of grain mixture should be increased grad-



COW AND CALF IN MATERNITY STALL

Unless the herd is at pasture, a cow should be put into a thoroughly cleaned and disinfected box stall at least 2 or 3 days before the expected date of calving. (From New York State College of Agriculture, Cornell University.)

ually until the cow is on full feed. However, where there has been trouble from ketosis in a herd, it is important to get cows on full feed as soon after calving as can be done without throwing them "off feed." (1087) It may take 3 weeks or more to get high producers on full feed, while lower producers can be fed their usual allowance somewhat sooner.

If the udder of a cow becomes swollen and congested, the amount of grain mixture should be reduced. Applying cold water carefully to the udder with a hose, followed by thorough milking, will relieve the congestion. This process should be repeated 4 to 6 times a day, if necessary.

1086. Milk fever.—Dairymen with experience know that their best cows, except heifers, are apt to have milk fever during the first few days after calving. This is caused by a lack of calcium in the blood, produced by the heavy drain on the supply of this mineral when the cow begins to secrete a large amount of milk. It has been stated previously that the parathyroid glands normally regulate the amount of calcium in the blood in some manner. (**54**) Later in lactation the cow is able to draw on the store of calcium in her skeleton when she does not secure enough from her food. At the outset of lactation the parathyroid glands seem to be unable in some cases to meet the demand for calcium, and milk fever results.

The incidence of milk fever, or parturient paresis, is highest in high-producing cows 5 to 10 years old, and Jerseys are more susceptible than other breeds. First calf heifers are rarely affected.

The usual treatment for milk fever is the injection of a solution of calcium gluconate or other calcium salt into the jugular vein or mammary veins, to raise the calcium content of the blood. The older method of treatment was to inflate the udder with air, which stops milk secretion by the increased pressure in the udder, and thus prevents the drain on calcium for milk production. The method is effective, but there is danger of infecting the udder with mastitis. However, the inflation method is still used in cases which are not cured by the injection of a calcium salt.

Some dairymen follow the practice, in the case of high-producing cows, except heifers, of leaving some milk in the udder at each milking for a few days after calving, in order to reduce the milk secretion. Others believe that prepartum milking lessens the tendency for milk fever to develop. However, in Mississippi and Wisconsin tests partial milking was not effective in preventing it,[27] and neither was prepartum milking in Wisconsin trials.[28]

In recent Ohio experiments milk fever has been prevented in susceptible cows by giving in the feed extremely large doses of vitamin D daily for at least 3 days and preferably not more than 7 days before calving, and 1 day after calving.[29] The daily dose is 30 million units of vitamin D in the form of dry irradiated yeast or else irradiated ergosterol in oil. This dosage should not be continued for a longer time, as this great amount of vitamin D is toxic if continued too long. If a cow does not calve by the expected time, the dosage should be discontinued until she calves, and the treatment given again for the day after calving. The high dosage of vitamin for the short time seems to prevent the drop in the calcium content of the blood, either by increasing the assimilation from the food or by mobilizing the calcium store in the skeleton.

Another method of prevention recently developed through California experiments is to feed susceptible cows a ration very high in phosphorus and extremely low in calcium for a month before calving.[30] In this method the cow is fed only 5 to 8 lbs. a day of low-calcium hay, such as oat hay or grass hay with no legumes, and is allowed no other roughage. She is fed 8 to 12 lbs. a day of a low-calcium concentrate mixture to which is added 5 lbs. of sodium phosphate per 100 lbs. of the mixture. It is believed that this method of feeding forces the parathyroid gland to increase its activity and draw on the calcium store in the skeleton.

This method of prevention was ef-

fective in most cases. However, it has the disadvantage that high-producing cows can regain their store of calcium, lost during the height of milk production, only during the dry period and the last part of the lactation. Where this method is tried, it is important that the cows get an abundance of legume forage, high in calcium, during the latter part of the lactation period and during the first part of the dry period, before they are placed on the calcium-deficient ration.

1087. Ketosis, or acetonemia.—Ketosis, or acetonemia, is a serious disease in some dairy herds, especially of high-producing cows. Some of the symptoms resemble milk fever, but it does not usually occur until several weeks after calving. In ketosis there is a rapid fall in milk yield, a loss of weight, digestive disorders, drowsiness, and sometimes pronounced nervous symptoms.

Ketosis is apparently caused by an insufficient supply or faulty utilization of carbohydrates in the body, resulting in a serious deficiency of glucose in the blood. The trouble may be brought on by various causes or stresses, but the chief cause is the drain on the glucose supply of the blood in high production. The lack of carbohydrates causes an increased metabolism of fat, and an accumulation of certain normal products of fat metabolism (called ketone bodies) which are toxic when present in excess. The disease has usually been treated by the injection of a glucose solution into a vein, generally combined with the feeding of molasses or sugar.

Recently, Shaw and associates of the Maryland Station have found that ketosis can be cured, except in cases complicated with other diseases, by the intramuscular injection of the hormone cortisone.[31] Sometimes a second or third injection is needed. The hormone called ACTH (or corticotropin) has also been used with success. Certain cortisone derivatives are even more potent than cortisone. These hormones restore the blood level of glucose.

Still more recently, Schultz of the New York (Cornell) Station has had good results in curing uncomplicated cases of ketosis by feeding sodium propionate, a relatively cheap compound, for 3 to 10 days at the rate of one-quarter pound daily, divided into two doses, mixed with the grain.[32] In severe cases where the cow is eating little or no grain, one-half pound of the sodium propionate is administered by capsule or drench.

In a test with 50 pairs of cows, one in each pair fed sodium propionate and one not, Schultz has also had good results in preventing ketosis by feeding one-quarter pound of it per head daily in the grain mixture for 6 weeks after calving.

Certain other products may help to prevent ketosis, but more data are needed to warrant conclusions concerning their effectiveness.

Insufficient feed before or after calving may tend to produce ketosis. It is therefore not advisable to reduce the amount of concentrates too much before calving, and it is best to increase the feed intake after calving as rapidly as is safe. Some feed molasses or another form of sugar for 2 or 3 weeks after calving, but this is of doubtful value as a preventive of ketosis. Tests have shown that supplements supplying vitamin A, the B-complex vitamins, cobalt, or choline are not effective in preventing or curing ketosis. There may be more trouble from it when the cows have only poor roughage, such as cottonseed hulls.

IV. Care of the Milking Herd

1088. Shelter and comfort.—On dairy farms in the northern states the cows are generally housed during winter in closed stables, and confined by stanchions or sometimes by ties or in stalls. The cows are kept in the stable, except that they are usually turned out for exercise in suitable weather for an hour or so a day. During the pasture season the cows are commonly outdoors, except at milking time.

Well-fed dairy cows do not need warm quarters in winter, even in cold climates. This is because they are kept warm by the large amount of heat produced in their bodies in the digestion

and utilization of their liberal rations. (228) Even in severe winter weather in the northern states, there is no benefit from a higher temperature than is provided by a well-built stable which is thoroughly insulated and has an efficient ventilating system.

It was concluded in a national survey of requirements for dairy barns that stable temperatures not lower than 35° to 45° F. were satisfactory in winter for dairy barns in the northernmost states.[33] It was advised that the barn should be ventilated so that the relative humidity of the air did not exceed 75 per cent under average weather conditions and 85 to 90 per cent on extremely cold days.

In studies by the United States Department of Agriculture and the Wisconsin Station it was found that the optimum winter stable temperature for cows in stanchions and moderately well fed was about 50° F.[34] There was very little decrease in milk production at 45°. At 60° to 65° the milk yield was above average, but the fat percentage was slightly reduced and the cows seemed less comfortable. At the higher temperature there was much more trouble from cowpox. The lower temperature was preferred by the milkers, and the stable odors were less pronounced.

Even in cold winter weather, well-fed dairy heifers over a year of age thrive when housed in an open shed, protected from prevailing winds. Many experienced dairymen believe that heifers housed thus and allowed to run out at all times into an exercise paddock are apt to develop into more rugged cows than heifers which are confined to a warmer stable in winter and allowed less exercise.

Though housing yearling heifers in an open shed is excellent from the standpoint of the thrift of the heifers, experiments indicate that in cold climates heifers thus housed may require considerably more feed than those in warmer quarters. This is because dairy heifers are fed less liberally than cows in milk, and therefore less surplus heat is produced in their bodies.

In Maine, North Dakota, and South Dakota trials heifers housed in an open shed or in a barn with an open door, through which they could run in and out, gained less and required considerably more feed than others housed in a warmer barn.[35]

For the comfort of dairy cows swinging stanchions are much preferable to the old-fashioned rigid ones. Many stanchion-type dairy barns have platforms too short and space for each cow too narrow for the larger cows in the herd. In such a barn udder and other injuries are more frequent.

Especially with long stalls, electric cow trainers keep the cows cleaner.[36] This device is suspended just above the cow's shoulders and is connected to an electric fence controller. When she humps up her back to defecate, she gets a very mild electric shock and steps back, so that the droppings fall in the gutter, instead of on the platform.

High-producing cows may yield slightly more milk when they have the freedom of individual box stalls, instead of being confined in stanchions. However, this increase, which will probably be less than 4 per cent, is not enough to pay for the extra labor and bedding required and the extra cost of housing, except in the case of cows on advanced registry test.[37] In a West Virginia experiment cows kept cleaner and had fewer injuries in "comfort" stalls than in tie-chain stalls which were smaller.[38] There was no difference in the amount of bedding needed.

For the comfort of the cows and for cleanliness, sufficient bedding should always be used. The various common bedding materials are discussed in Chapter XXIV. So that milk of good sanitary quality can be produced, the barn and the cows should be kept clean. Though grooming the cows may not increase the yield of milk appreciably, it is important from the sanitary standpoint. (1066)

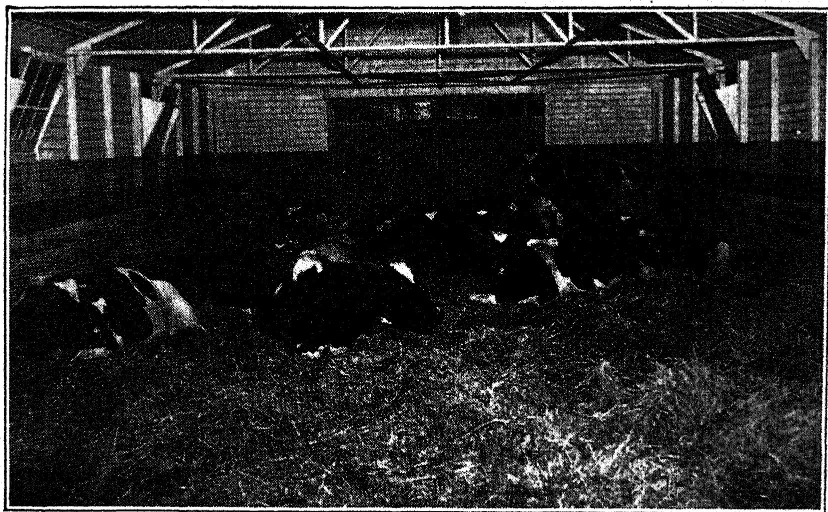
The importance of an efficient ventilating system to provide fresh air, to maintain a proper temperature, to reduce the humidity, and to remove dampness and foul odors, has been emphasized previously. (246) For proper light, there should be a sufficient area of windows,

well distributed in the stable. A common rècommendation has been 4 square feet of glass area per cow, but in cold regions 3 to 3.5 square feet per cow is sufficient. The smaller glass area cuts down the loss of heat from the stable in winter.

It is well to disinfect the stable thoroughly at least once each year, to aid in checking any possible spread of disease. The benefits from dehorning cows have been pointed out in the previous chapter.

fed their grain. The hay and other roughage is best fed in a paved area adjacent to the loafing area. This is not bedded, but is cleaned daily or frequently. The loafing area is kept well bedded and is cleaned only when the manure has accumulated to a considerable depth. Much more bedding is needed to keep the cows clean than when they are housed in a stanchion barn.

The loafing-shed and milking-room system has certain definite advantages and also certain disadvantages. In the



LOOSE HOUSING SYSTEM OF HOUSING COWS

The cows have the freedom of an open shed, except at milking time, when they go in relays to a milking room. (From Wisconsin Station.)

The hoofs of dairy cattle should be trimmed when necessary to prevent them from becoming so long that the feet are injured. When the cattle are on pasture, the hoofs generally wear down sufficiently, but during the winter trimming is often necessary.

1089. Loose-housing.—During recent years many dairymen have adopted the loose-housing, or pen-barn, method for their dairy cows. In this system the cows have the freedom of an open loafing shed or a large stable with a door open to the outside, except at milking time when they go in relays to a milking parlor. Here they are milked and usually

loafing-shed method the cows are more comfortable and there are fewer injuries to udders, hocks, and knees. The cows keep cleaner, if enough bedding is used. The trouble from mastitis may be reduced. When the manure is allowed to accumulate in the pen barn and is only cleaned out a few times each winter, losses in fertility value can be lessened. (995) It is much easier to detect heat periods in the cows, but cows in heat may disturb the rest of the cows. The herd may be increased in size more readily, by building a cheap addition to the shed. The stable may easily be adapted to other types of livestock. If a new build-

ing is to be built, the cost of housing will be less with this method.

The chief disadvantage is the much greater amount of bedding that is required to keep the cows clean. Where there is a shortage of bedding, this may be a very serious disadvantage. There are also other disadvantages. In the loafing-shed method of housing, boss cows are often troublesome. Sometimes, certain cows must be housed elsewhere or disposed of for this reason. The cows must be dehorned in this method. In cold climates it is necessary to heat the milking room and also preferably the quarters for young calves the first few weeks of their lives. The cows grow heavier coats of hair, and the herd does not show off so well to men who may wish to purchase dairy animals. Disease may spread more rapidly in this method of housing. In some market milk areas, the health regulations may not permit this method of housing dairy cows, though milk of very satisfactory quality can be produced by it if a proper amount of bedding is used.

Even in the extreme northern states, in the several tests of the loose-housing method by the experiment stations there has been little or no difference in the feed required by cows thus housed and those in much warmer ordinary stables.[39] This is because of the surplus heat produced in the bodies of well-fed cows in digesting and utilizing their liberal rations. Also, although the air temperature in the loafing shed may be very low in winter, the temperature in the manure just below the straw bedding is always warm, ranging between 70° and 100° F., regardless of the weather. This is due to the heat produced in the slow fermentation of the mass of manure. The cows therefore always have a warm bed to lie upon, even in zero weather.

1090. Flies and fly sprays.—Every dairyman should endeavor to rid the premises of flies as much as possible. Flies not only annoy the cows and attendants, but are also a source of contamination. Control of flies by spraying has become more difficult because in some areas the flies have become resistant to lindane and methoxychlor, the two chief residual sprays approved for use in dairy stables.

The most effective method of fly control is therefore preventing their breeding by careful cleanup of all possible breeding sites. Pens and boxstalls should be cleaned at least twice a week in summer and the manure should be spread immediately or put at a considerable distance from the dairy barn. House flies can travel at least 2 miles.

For spraying a dairy stable an insecticide should be used which is approved by the Food and Drug Administration for such use, instead of using an insecticide such as DDT, which passes into the milk, thus contaminating it.

The sharp decline in milk production which often occurs in midsummer is sometimes attributed to the annoyance of the cows by flies. Investigations have indicated, however, that in most dairy regions the decline is usually due more commonly to the heat or to a scanty supply of pasturage at this time.

For spraying dairy cows, one should use a pyrethrum spray, or one of the other sprays approved for this purpose. In numerous experiments, spraying cows with the older-type commercial or home-mixed fly sprays usually made little or no increase in milk yield.[40] In some tests heavy applications of oil fly sprays even caused a decided drop in milk yield, especially in hot weather. This was probably because the film of oil on hair and skin raised the body temperature in hot weather by preventing the evaporation of water from the skin. Some fly sprays may temporarily injure the parts of the skin exposed to the sunlight, if applied daily over a considerable period. For calves a water-emulsion or wettable-powder spray should be used, as oil-base sprays may produce serious skin injury, somewhat similar to X-disease.[41] Medicated stock salts, sold as a fly repellent, were found ineffective in Kansas and Oklahoma tests.[42]

1091. Exercise.—Except in stormy or unusually cold weather, dairy cows should be turned out daily during winter for exercise in a sunny yard sheltered

from prevailing winds. This will aid in keeping them thrifty, and the exposure to sunlight will help provide vitamin D. Moderate exercise also tends to increase slightly the yield of milk and the percentage of fat. (**1066**) Forcing cows to stay outside a good share of the day in cold weather wastes feed and may reduce the yield severely. In the South, winter pasture should be provided whenever possible, in order to reduce the cost of feeding the herd.

1092. Frequency and order of feeding.—The most common practice in dairy herds is to feed the grain mixture before milking, and then after milking to feed the silage or other succulent feed which might taint the milk if fed before milking. When the cows are milked in a milking parlor, usually the cows are fed their grain mixture at that time. The hay is generally fed after the silage has been cleaned up. With cows milked more than twice a day, part of the daily allowance of grain mixture is usually fed before each milking and the hay and silage only at morning and night. If one wished to have the cows eat the maximum amount of hay, the hay consumption can be increased somewhat by supplying fresh hay more than twice a day.

Hay and other dry forages should not be fed until after milking, as they are apt to fill the air with dust. Also, alfalfa hay may produce a marked flavor in milk if fed less than 4 hours before milking.

The particular order of supplying the various feeds is not important, but the same order should be followed from day to day and the cows should be fed and milked at regular times. A lack of regularity is apt to decrease the yield of milk and fat somewhat.

Some dairymen put the grain mixture on top of the silage in the manger, and this is a good plan if one is feeding a liberal allowance of a heavy mixture, containing no bulky feeds. Cows which are accustomed to getting their grain before milking may tend to be restless and "hold up" their milk if the grain is not fed until after milking, but it will not take them long to get used to the change.

It is sometimes advocated that dairy cows be fed only once a day, so as to save labor.[43] However, in a trial of this method by the United States Department of Agriculture, cows fed twice a day ate 10 per cent more alfalfa hay, produced 6 per cent more milk, and gave a greater net return over cost of feed and labor, than when fed only once a day.[44]

1093. Milking.—Extensive recent investigations have proved the great importance of proper milking of dairy cows. In particular, these studies have shown that rapid milking not only saves much time, but also reduces the trouble from mastitis and even tends to increase the yield. This is due to the following interesting facts:[45]

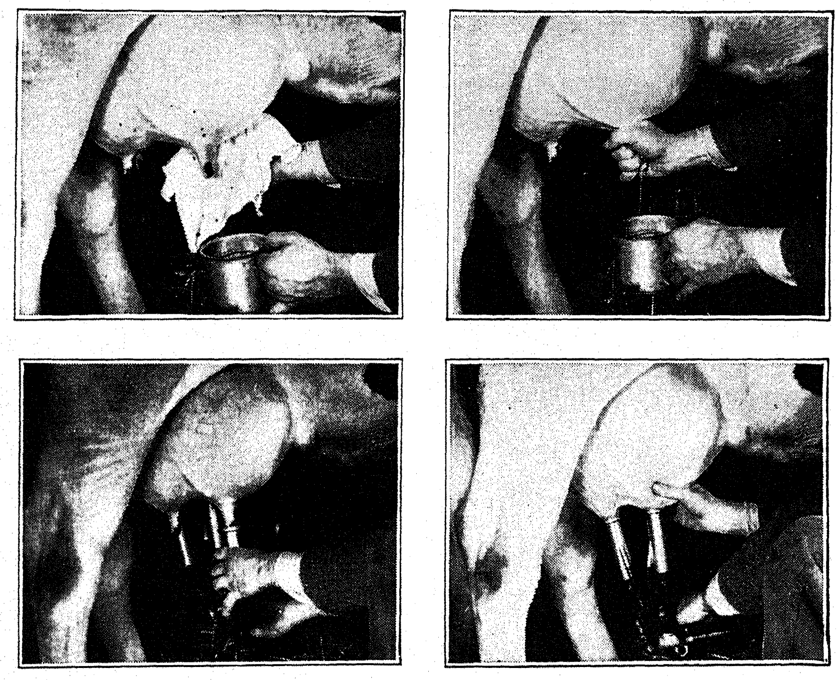
As has been pointed out in Chapter X, the secretion of milk is a continuous process and most of the milk secured at each milking is present in the udder when milking starts. However, only a small part is in the milk cistern and the large ducts. Most of it is held in the millions of tiny alveoli and in the small ducts. These are so small (each alveolus holding only a fraction of a drop) that the milk is held firmly by capillary action. It cannot be removed by the suction of machine milking or by the pressure of hand milking.

However, if the proper stimulus occurs, the cow "lets down" her milk. This is not a voluntary action on the part of the cow, but a reflex or automatic one caused by a hormone which is secreted by the pituitary gland at the base of the brain.

When the proper stimulus takes place, nerve messages are carried to the cow's brain, causing the hormone, called oxytocin, to be ejected into the blood. It is then carried to the tissues of the udder where it causes muscular fibers surrounding the alveoli and small ducts to contract. This squeezes the milk into the larger ducts and the milk cistern, and we say the cow has "let down" her milk.

The effect of the hormone lasts only a few minutes. Therefore the largest yield of milk is secured when the cow is milked rapidly, before the smaller muscular fibers relax.

If the cow becomes excited or frightened, another hormone called adrenalin, which is produced by the adrenal glands, has the opposite effect. It interferes with the oxytocin. Then we say that the cow has "held up" her milk, because the milker can get only the small amount the water. The udder of a cow should not be washed more than 1 to 3 minutes before milking is to start, for it takes even less time than this for the action of oxytocin to cause the "let down" of the milk. If the start of milking is delayed too long, the effect of the oxytocin may



STEPS IN EFFICIENT MACHINE MILKING

Upper left: Stimulate the cow to let down her milk by washing her udder with warm chlorine water one minute before putting on the machine.

Upper right: Check each quarter for mastitis by using a strip cup.

Lower left: Put on the teat cups about one minute after preparation.

Lower right: Strip the cow by machine. When the teat cups start to crawl up on the udder, they should be pulled part way down, using the free hand to massage the udder. Short-tube machines may not need this downward pull. (From New York State College of Agriculture, Cornell University.)

already present in the milk cistern and large ducts.

Cows usually like to be milked, and anything which is commonly associated with the milking process may cause them to "let down" their milk. Thus, cleaning the udder with a cloth or paper towel wet with warm water is an effective way of providing the stimulus. For sanitary reasons chlorine or a quaternary ammonium compound should be added to not last, and the cow may "hold up" her milk. If some cows tend to "let down" their milk as soon as milking starts in the barn, they should be milked first.

These recent studies provide an interesting explanation for the well-known fact that regularity in feeding and stable management is necessary to secure the largest yields from good cows. Also, the kind milker who gains the confidence of

cows secures more milk from them than a rough or indifferent person.

Incomplete milking tends to reduce the milk yield,[46] and it may increase trouble from mastitis in cows whose udders are infected with the disease. However, it must be remembered that milk secretion is a continuous process. Therefore a cow can never be milked "bone dry."

1094. Machine milking.—Because of the saving of labor and also the difficulty of securing good hand milkers, milking machines have come into common use on our larger dairy farms. Extensive trials by the experiment stations show that satisfactory results, both in yield and quality of milk, are secured when good milking machines are handled by careful operators, who use proper methods of milking and who thoroughly cleanse and sterilize the equipment. When the newer method of rapid machine milking is properly used, the production is equal to good hand milking, and the trouble from mastitis is no greater.[47] On the other hand, with the older method of machine milking in which it often took 9 to 10 minutes per cow, the production tended to be less than from first-class hand milking and trouble from mastitis was greater.

To secure the best results by machine milking, certain rules must be carefully followed: [48] (1) The cow should be stimulated to let down her milk by washing her udder with warm water 1 to 3 minutes before putting on the machine. (2) The machine should be operated according to the manufacturer's directions. Increasing the vacuum or altering the rate of pulsation may make milking unpleasant for the cow. (3) The cows should be stripped by machine. When the teat cups start to crawl up on the soft tissues, they should be pulled part way down, using the free hand to massage the udder. Pulling the teat cups down prevents a pinching action which would shut off the milk ducts leading into the teats, and thus cause incomplete milking. (4) Do not leave the machine on the cow after milk stops flowing. Leaving it on longer may congest the delicate tissues and lead to mastitis.

If this routine is followed, most cows will milk out sufficiently clean in 3 to 4 minutes without any hand stripping, except perhaps a few squeezes on each teat to see if the quarter has been milked clean.

In cost accounting studies on dairy farms the amount of total man labor per cow a year has usually been 18 to 31 hours less per year in herds where milking machines were used than where the cows were milked by hand.[49] The time needed for milking can be reduced still more by the use of a modern milking parlor.

Care must be taken not to spread mastitis by the use of a milking machine. The teat cups should be rinsed and then dipped in a chlorine solution before being placed on the next cow. Cows having mastitis should always be milked last.

1095. Hand milking.—The same method of stimulating the cow to let down her milk should be followed in hand milking as in machine milking. She should then be milked as rapidly as possible.

It is always desirable to have the same man milk each cow at every milking, but a change will not usually affect the yield of milk appreciably, if the new man is as good a milker as the former one.[50] Regularity in the time of milking is highly desirable, especially in the case of high-producing cows. However, cows of average production can apparently be milked with occasional irregularity without any appreciable decline in yield, provided they are fed regularly.

In milking cows thoroughly so as to get all the strippings, the best milkers generally manipulate the udder to some extent toward the end of milking. An upward pressure on each quarter for a few times when milking is nearly completed helps to bring the last milk into the teats, where it can be drawn. More elaborate methods of massaging and manipulating the udder are not necessary.[51]

1096. **Regularity and kindness.**—Regularity and kindness are even more important with dairy cows than with other farm animals. The highest-yielding cows are usually of nervous temperament, and especially with such animals, excitement often causes a sharp decrease in yield. Cows being driven should not be hurried, and attendants should never strike or otherwise abuse them.

Good dairymen now realize the fact brought to public attention by W. D. Hoard of Wisconsin that dairying is based on the maternity of the cow, and treat their animals accordingly. As Haecker wrote: "If you so handle the cows that they are fond of you, you have learned one of the most important lessons that lead to profitable dairying. . . . A cow's affection for the calf prompts the desire to give it milk; if you gain her affection she will desire to give you milk." [52]

V. The Cost of Milk Production

1097. **Determining the cost of milk production.**—Many investigations have been conducted by the experiment stations to find the cost of milk production in the various states. These studies have not only furnished much information on this important subject, but have also shown how a farmer can reduce his own costs and increase his net returns, or even convert a loss into a profit.

In determining the cost of milk production the expenses are commonly grouped as follows:

(1) The combined cost of feed and bedding is by far the largest single item of expense, generally forming from one-half to two-thirds of the total cost. This expense will vary widely, depending on the prices of feeds, the average production of the herd, and the economy of the rations used.

(2) Next in importance is the cost of man labor in milking and feeding the cows, cleaning the stables, handling and hauling the milk, etc. This makes up at least one-fifth the total cost. Commonly, all the man labor is figured at the current rate for farm labor. Then an item is sometimes added to cover managerial ability and business risks, a common estimate for this being 10 per cent of the other total costs.

In addition to these two main expenses, the following must be included: (3) The building charge, which includes interest, insurance, depreciation, and repairs on the part of the barn occupied by the cows and by storage for their feed; (4) the equipment charge, which covers cost of milk utensils or machinery, tools, etc.; (5) the cow charge, which covers depreciation, interest, taxes, and mortality risk on the cows; (6) the pro-rata cost of keeping the sire or the cost of breeding service; and (7) miscellaneous expenses, including cash paid for hauling milk, horse and tractor labor, cost of supplies, veterinary services, cow-testing association fees, etc.

The depreciation charge is a larger item than often believed, because the average useful life of dairy cows in the herd after they first calve has been found to be only 4 to 5 years.[53] While many cows have a much longer useful life, the cows are replaced within this period, on the average, because of low milk yield, failure to breed, injury, or disease.

Where most of the replacements are purchased instead of being raised on the farm, the productive life of the cows in the herd is usually much shorter. For example, in a study of Connecticut dairy herd improvement association herds, it was found the average productive life of the cows in herds where the replacements were purchased was only 2.6 years, while it was 5 years in herds where the replacement heifers were raised on the farm.[54]

The annual depreciation may be estimated by computing the difference between the cost or value of the cow when she first calves or is purchased and the price she will bring when discarded, and dividing this difference by her number of years of production in the herd. For example, if a cow is worth $200 when she first calves, then has a useful life of 5 years, and finally brings $110 when sold for beef, the annual depreciation

will be one-fifth of $90, or $18. The mortality risk is not large, when the health of the herd is properly safeguarded, being only about 1.5 per cent a year.

From the total gross cost of keeping the cows there must be deducted the value of the manure and the value of the calves at a few days of age. The value of the calves will of course vary widely, depending on their breeding. In studies of the cost of milk production where some of the herds include purebred cows, these are usually valued at the price of grades of similar productive capacity, and the calves credited at veal or grade prices. This is done so as to differentiate between the financial returns from producing milk and from breeding purebred cattle.

1098. Annual cost of keeping cows.—Many studies have been made of the cost of milk production on dairy farms. The method by which the cost is determined is shown in one of the most recent studies, on 113 farms in dairy districts of west-central New York for 1953–54.[55] On these farms the average milk production per cow was 8,439 lbs. of milk and 312 lbs. of fat. The feed consumption per cow for the year averaged: Home-grown grain, 1,946 lbs.; purchased concentrates, 1,036 lbs.; hay, 2.4 tons; silage, 5.3 tons; and pasture during the season.

The costs per cow were: Feed, $207.04; labor, $101.72; building charge, $15.11; equipment charge, $9.06; depreciation on cow, $16.16; interest on value of cow, $10.82; breeding cost, $6.00; bedding, $10.21; milk hauling, $17.87; and miscellaneous, $15.45; making the total gross cost per cow $409.44.

From this was deducted a credit of $11.38 for calves and of $10.50 for the value of the manure. This made the net cost $387.56 per cow, or the net cost per 100 lbs. of milk $4.59.

The following table shows the average milk yield per cow and the amounts of feed and labor required in studies in other dairy districts.[56]

It will be noted that the annual milk production per cow in these studies was decidedly higher than the average yield in this country.

Feed and labor required by dairy cows

	Michigan	Illinois	North Carolina	Washington
Av. yield per cow				
Milk, lbs. . . .	8,186	8,328	6,318	. . . .
Fat, lbs.	303	302	275	308
Feed and bedding				
Concentrates, lbs.	2,840	2,352	2,961	2,060
Hay, lbs.	4,343	2,552	3,051	5,400
Other dry roughage, lbs. .	503	311	480	*
Succulent feeds, lbs. . .	5,078	7,048	4,497	3,400
Pasture, days	149	160	*	*
Bedding, lbs.	*	880	*	*
Labor				
Man, hrs. . . .	132	118	184	163

* Amount not stated.

1099. Formulas for estimating cost of milk production.—Various simple formulas are sometimes used for estimating the cost of milk production. In these formulas all the costs are reduced to terms of feed and labor. Therefore, by taking the current prices for feeds and for labor, a more or less approximate estimate of the cost of producing milk can readily be made at any time. In using these items as a basis for calculating the cost of producing milk, it is assumed that as the prices of feeds and labor rise or fall the other items of expense and the credit items will change accordingly.

The way in which such a formula is used is illustrated by a recent formula for estimating the cost of producing milk in the market-milk districts supplying the New York metropolitan area.[57] This region covers most of New York State and extends into adjoining states.

According to this formula, the cost of producing 100 lbs. of milk in this region may be estimated by first totalling the cost of 33 lbs. of concentrates, including home-grown grain; 71 lbs. of hay and other dry roughage; 128 lbs. of silage; 2.3 days of pasture; and 2.5 hours of man labor. This total represents about 80 to 85 per cent of the total net cost, depending on the price level of feeds

in relation to other costs. Therefore it must be increased accordingly to find the estimated total net cost of producing 100 lbs. of milk.

To illustrate the use of the formula, let us assume that the cost of a good concentrate mixture, including some home-grown grain, is $65 a ton; of hay, $20 a ton; of silage, $8 a ton; of pasture, 7 cents per cow a day; and of farm labor, 65 cents per hour, including board. At these prices, the total cost of feed and labor according to the formula will be $4.08 per 100 lbs. of milk. If this is 85 per cent of the total net cost, the total cost is found by dividing $4.08 by 85 and multiplying the quotient by 100. This will give us $4.80 as the estimated total yearly cost of 100 lbs. of milk at the prices stated for feed and labor.

1100. Seasonal cost of production.—Every experienced dairyman knows that it costs much more to produce milk in winter than in summer when the cows are on pasture. This is because pasture is a cheap feed, and also because much less labor is required in producing each 100 lbs. of milk when the herd is on pasture than under winter feeding conditions. The difference in cost between winter and summer is well shown in studies on the cost of milk production in 5 New York counties.[58] Charging man labor at a uniform rate throughout the year, the cost of milk production was 82 per cent greater from October through March than in the period from April through September.

Since it costs less to produce milk in the summer, the natural tendency will be for dairymen to concentrate production in the more profitable months by having their cows freshen in the spring. Therefore in order to secure a steady supply of milk for city consumption, the price paid farmers in market milk districts must be enough higher in winter than in summer to offset the difference in cost of production.

It has been shown in the previous chapter that the annual yield of milk is somewhat larger from cows calving in fall or early winter than from those freshening in the spring or summer. (**1061**) However, where milk is produced for butter or other manufactured products in districts far from the metropolitan areas, summer dairying may be most profitable, because of the low cost of production on pasture.

1101. Reducing the cost of milk production.—The studies of the cost of milk production have shown that the following are the most important factors in reducing the cost:

1. *Large average yearly yield.* It has been emphasized in the previous chapter that a large average yearly yield per cow is the most important factor affecting the cost of milk production. (**997**) To secure this, the dairyman must first of all have good cows and then cull his herd each year to get rid of unprofitable animals. (**1005**) Next, he must feed and care for these good cows so they are given full opportunity to yield a profitable amount of milk.

2. *Balanced rations.* Cows of high productive capacity cannot produce a good yield unless they are fed adequate rations, properly-balanced in protein and supplying ample minerals and vitamins. It has been clearly shown in the studies of the cost of milk production on dairy farms that a lack of protein seriously reduces the yield of milk and consequently the net returns.

3. *A liberal but not wasteful amount of feed.* A large yield of milk is impossible without a liberal supply of feed, as has been emphasized previously. However, wasteful feeding of concentrates must be avoided at all times. Therefore the amounts fed to the individual cows should be strictly adjusted to their milk yields.

When concentrates are very expensive in comparison with roughage, it is most economical to feed less concentrates than are needed to meet the recommendations of the feeding standards. It is then especially important that the roughage be of excellent quality and that it be fed with great liberality. (**1029**)

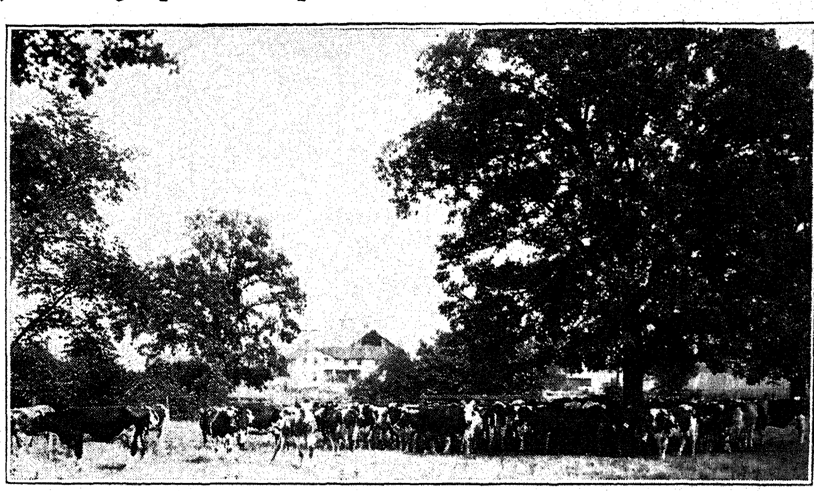
4. *Low-cost rations throughout the year.* To keep the feed cost as low as possible and yet secure high production, good yields of crops of the best feeding

value must be raised. The cost of efficient rations during the barn-feeding season can generally be kept at a minimum by providing an abundance of legume hay or of mixed hay high in legumes, along with good silage where silage is an economical feed. (**1022**) With such roughage it is not necessary to feed as much concentrates to secure high production, as when the roughage is poorer.

For economical summer feeding, it is necessary to provide excellent pasture over just as long a period as is possible. Enough concentrates must be fed in addition to keep up milk production and prevent the cows from running down in condition. If pasture becomes scanty, it must be supplemented by feeding silage, hay, or soiling crops. (**1079**)

5. *Maintaining herd health and avoiding heavy depreciation.* Unless great care is taken to prevent disease and maintain the health of the herd, disease will destroy all possible profits. It is especially important to avoid losses from Bang's disease (infectious abortion) and to handle the cows so that mastitis is reduced to a minimum.

The necessary replacements for the milking herd can usually be provided most economically by raising properly the heifer calves from the best cows in the herd, sired by a bred-for-production purebred bull. In dairy districts where the cost of feed is not unduly high, many farmers reduce the cost of depreciation to a minimum by selling cows when they are in their prime and will bring a good price, instead of waiting until they must be discarded as culls. They replace these animals with good heifers which they have raised. Careless dairymen may sometimes raise just as many calves for replacement, but because of disease and poor management, never have any cows to sell except culls.



ENOUGH COWS SHOULD BE KEPT TO MAKE AN ECONOMICAL UNIT

If dairy cows are to provide the main source of income on the farm, a sufficient number must be kept to make an economical unit. The exact number should depend on the local conditions.

6. *A herd of sufficient size.* If dairy cows are to provide the main source of income on a farm, a sufficient number must be kept to make an economical unit. If there are only a few cows in the herd, the gross income will necessarily be small, labor will be employed less efficiently, and if a bull is kept, the bull cost per cow will be greatly increased.

7. *Efficiency in the use of labor.* Many dairymen do not fully realize the importance of efficiency in the use of labor to reduce the cost of milk production. There is a great range in the num-

ber of hours of labor spent in feeding and caring for the cows on individual farms, even where the milk is of the same quality from the sanitary standpoint. To reduce the amount of labor the barn must be arranged conveniently and labor-saving equipment must be provided, such as drinking bowls, grain cart, and silage cart. As has been pointed out in this chapter, the loose-housing method saves considerable labor. Also, labor is considerably reduced by the rapid milking method and by the use of a milking parlor. In a large herd an automatic barn cleaner saves enough hard labor to be a good investment.

Considerable time can be saved by efficient planning of the daily routine and convenient location of tools and supplies. The great saving of labor that can often be made is shown by the results secured by a New England dairyman who was already an efficient farmer.[59] This is evident from the fact that he alone did all the work on his 150-acre farm and cared for his herd of 22 cows, except for an extra man for about a month a year. By rearrangement of the stable, providing labor-saving but inexpensive equipment, better location of tools and supplies, and improvement in the work routine, the time spent on chores was reduced from an average of 5 hours 44 minutes a day to only 3 hours 39 minutes. The daily travel in doing the chores was cut from 3.25 to 1.25 miles a day. These savings would mean in a year more than 2 months of time and 730 miles of walking.

VI. Feeding and Caring for Cows on Official Test

1102. Cows on official test.—The feeding and management of cows fed for maximum production on official test is fully as much an art as a science. The completion of a notable record depends largely upon the intelligent feeding and painstaking care of an expert herdsman. The rations and methods used by leading breeders differ widely. In fact, nearly every champion cow has received a somewhat different ration from other record-breaking cows. This indicates that there are no secret formulas or methods of management which are outstanding in their superiority over all others.

The following brief summary on the feeding and care of test cows is presented with the hope that it may be helpful to those who have not had experience in this field.[60]

1103. Fitting cows for official test.—The highest production of which a cow is capable can be secured only when she is well fitted, or fattened, before she freshens. When a cow calves in high condition, her production of milk and fat is considerably increased during the early part of her lactation, because she can draw on the store of fat in her body. (**1062**) Also, in the case of cows of the lower-testing breeds, the richness of the milk is generally raised to a marked extent during the first few weeks of lactation.

A cow that is to be run on official test should be completely dry about 60 days before she is due to freshen. A longer dry period is not necessary for proper fitting. If the cow is not in fair flesh during the latter part of the lactation period, she should be fed a little more liberally than if she were not to be tested the next lactation. Then she can be gotten into the desired condition in a 60-day dry period.

During the dry period the same concentrate mixture, or so-called "fitting ration," may be used in fitting cows for official test that is fed to the other dry cows in the herd. (**1082**) The amount to be fed will depend entirely on the condition of the individual cow. It should not be necessary to feed more than about 12 lbs. of concentrates daily. Extremely heavy feeding during the dry period is not economical, and may result in the cow having a poor appetite at the start of the test period.

It is a good plan to feed during the dry period the same roughages that will be used when the cow is on test. A liberal amount of well-cured legume hay or of mixed hay rich in legumes should be fed, so there will be a plentiful supply of carotene and vitamin D. Corn or sorghum silage is also excellent at this time.

1104. Feed and care before and after calving.—When the cow is to be kept in a box stall during the test period, she should be put in it a few weeks in advance of calving, so she will become used to her surroundings. The cow should be in the proper condition for freshening about 2 weeks before calving, because it may be

necessary to reduce the concentrate allowance considerably to prevent extreme congestion of the udder.

Some congestion is normal with cows of high productive capacity that are well fitted. However, the udder must not be allowed to become caked and hard. If this occurs, the cow must be fed scantily for a time after she freshens. This will result in her using up her body reserve of fat very rapidly. Rubbing the udder twice daily with a mixture of one-half cod-liver oil and one-half ethyl alcohol will do much to prevent undue congestion and to keep the udder soft.

Many breeders discontinue feeding the regular fitting concentrate mixture 10 days to 2 weeks before calving and give instead a "cooling ration." However, no change in the mixture is necessary if the cow is not constipated. It is essential that her bowels be in a laxative condition before calving. A warm bran mash is an excellent mild laxative. If necessary, the cow should be given a dose of mineral oil or Epsom salts.

Those who prefer to use a special "cooling ration" before calving feed such a mixture as 2 parts wheat bran, 2 parts ground oats, and 1 part linseed meal. For a day or so before calving, some breeders even feed no concentrates except a bran mash, or a warm mash made of equal parts of bran and whole oats.

The care of a test cow at calving time is little different from that for any other cow. (1084) The danger from milk fever is greater, however, and preventive measures should be taken at the first signs of its appearance. The calf should be removed after it has had one feeding.

1105. Getting the test cow on feed.—The cow must be gotten on feed as quickly as possible, but extreme care must be used not to force her too fast. For several days after calving she should be fed the same "fitting ration" that has been used during the dry period. For the first 24 hours, only about 1 lb. of the mixture should be given at each feeding. This may be sprinkled over an allowance of soaked beet pulp.

The amount to be fed after this will depend on the condition of the udder and upon the cow's appetite. If the cow is doing well, 6 to 8 lbs. a day of the fitting ration may be fed during the second to the fifth day. On the other hand, if the udder is badly congested, but little of the fitting ration can be fed until the congestion is over.

After the fifth day, if the cow has a good appetite and her udder is in satisfactory condition, the allowance should be gradually increased by adding a small amount of the mixture which is to be fed throughout the lactation period (the so-called "test ration"). A good plan is to increase the amount at the rate of 0.1 lb. per feed until full feed is reached. When the cow is on full feed, the fitting ration is then gradually replaced by the test ration.

At the first sign of a dull appetite, no further increase should be made until the cow seems ready to handle more feed. Concentrates should never be left before a cow, hoping she will eat the rest. If she needs the feed, she will eat it at once. In case the cow does not show an eager appetite, most experienced herdsmen reduce the concentrates for one or two feeds to allow her to become hungry.

Only a good herdsman can decide when a cow is actually on full feed. The object should be always to feed no more concentrates than are needed for maximum production. Forced feeding is a foolish practice. By crowding them on rich feeds beyond the safety point in an attempt to secure a little higher production, many valuable animals have unfortunately been ruined. They have failed to breed afterwards, their udders have been spoiled, or their digestive systems have been injured.

The upper limit of concentrates should be about 25 lbs. per head daily, not including soaked beet pulp which is often fed in addition, as is mentioned later. It is best not to feed first-calf heifers more than 15 lbs. per head daily of the concentrate mixture.

1106. Necessity of liberal feeding.—When maximum yields are desired, cows on test must be fed greater amounts of nutrients than are recommended in the feeding standards. This was well shown in experiments by Woodward of the United States Department of Agriculture, who compared the records of cows on official test with their records made under the usual system of feeding and care for cows not on test.[61]

When on official test the cows were full fed on concentrates, with a large quantity of alfalfa hay, a small amount of silage, and soaked beet pulp in addition. They were milked 3 times a day, were kept in box stalls, and were bred to freshen about 15 months from the previous date of calving. Because of the liberality of feeding and the other conditions favorable for a maximum yield, the cows yielded approximately 50 per cent more milk than during other lactation periods when they were fed according to usual good dairy practice.

When not on test, the cows received

fully as great an amount of nutrients as advised in the feeding standards for the amount of milk they yielded. They were kept in stanchions, were milked twice a day, and were bred to freshen about 12 months from the date of previous calving.

In addition to showing the necessity of liberal feeding and the best of care when maximum records are desired, these experiments emphasize the difference between records of production under such test conditions and records under ordinary herd conditions.

1107. Rations for test cows.—The "test rations," or concentrate mixtures, used by various breeders for test cows differ widely, but nearly all have certain general characteristics. They are usually made up of a considerable variety of palatable feeds; they include a goodly proportion of such bulky feeds as wheat bran, ground oats, and dried beet pulp, and in addition a sufficient amount of protein-rich feeds, such as linseed meal, soybean oil meal, cottonseed meal, coconut oil meal, distillers corn dried grains, and gluten meal or gluten feed.

When the cows are fed a liberal amount of legume hay or of mixed hay high in legumes, it is advisable to use a concentrate mixture that contains about 16 to 18 per cent protein. If a mixture is used which is considerably higher in protein, a large excess of protein will be furnished, which will throw an increased load on the kidneys. When little or no legume hay is fed, the concentrate mixture should have 19 to 20 per cent protein.

In order to provide plenty of fat for maximum production, the concentrate mixture should contain at least 5 per cent of fat. **(1020)** Since certain feeds may have a slight effect in increasing the fat content of milk, it is a good plan to include one or more of these feeds in the test mixture. Such feeds are coconut oil meal, soybeans, and palm-kernel oil meal. **(1064)**

A concentrate mixture that has given excellent results when used with legume hay in the Cornell University herd is: 400 lbs. ground corn or hominy feed, 370 lbs. ground oats, 400 lbs. wheat bran, 300 lbs. distillers corn dried grains, 300 lbs. coconut oil meal (old process), 200 lbs. linseed meal, 10 lbs. salt, and 20 lbs. steamed bone meal. This mixture contains about 18.5 per cent protein.

A concentrate mixture with about 20 per cent protein, recommended by Bender of New Jersey is as follows: 600 lbs. ground corn or hominy feed, 400 lbs. ground oats, 300 lbs. wheat bran, 250 lbs. linseed meal, 150 lbs. corn gluten meal, 150 lbs. cottonseed meal, and 150 lbs. brewers' dried grains.[62] To each ton are added 20 lbs. ground limestone, 20 lbs. steamed bone meal, and 20 lbs. salt.

A mixture having 19 per cent protein, recommended by Nevens of the Illinois Station, is: 560 lbs. ground corn, 200 lbs. ground oats, 200 lbs. wheat bran, 200 lbs. dried beet pulp, 400 lbs. linseed meal, 200 lbs. corn gluten feed, 200 lbs. cottonseed meal, 20 lbs. steamed bone meal, and 20 lbs. salt.[63] The considerable difference in these formulas well shows that no one concentrate mixture is preferable to all others. In these mixtures ground barley or other grain may be substituted for part or all of the corn.

A test cow should be supplied with as much well-cured hay as she will eat, for this is the best insurance that she will receive a plentiful supply of carotene and vitamin D. Legume hay or mixed hay high in legumes is much preferable to grass hay. If the latter is used, it should be early-cut and of good green color. First-cutting alfalfa hay is satisfactory, if it is well cured, and may even be preferable to second-cutting or third-cutting hay, which is sometimes too laxative. Second-cutting mixed hay, high in clover or alfalfa, is excellent. If the cows are in box stalls, the hay may be kept before them at all times in racks. Before each new supply of hay is put in the racks, any waste should be removed.

Opinions differ concerning the feeding of silage to test cows. When silage is fed, the allowance should be limited to 20 or 25 lbs. per head daily. If test cows are provided all the silage they will eat, they will consume so much of this bulky feed that they will not be able to eat as much concentrates as needed for maximum production.

Many experienced feeders of test cows prefer to use soaked beet pulp as a succulent feed instead of silage. The allowance is usually about 5 or 6 lbs. of dried beet pulp per head daily for cows of the smaller breeds and up to 9 or 10 lbs. for Holsteins. Some years ago the feeding of sliced mangels or sugar beets to test cows was a common practice in the United States. Since soaked beet pulp has been found to give just as good results, it is now generally used instead of roots, as it is much more convenient and also cheaper.

In summer, test cows should, if possible, be turned out on good pasture each day, but they should not be kept on pasture so long that they will fail to eat the desired amount of concentrates. When they are started on pasture in spring, they should not be left on

the pasture more than an hour the first day, for too large an amount of the green feed will be unduly laxative. The feeding of hay should be continued throughout the pasture season, to avoid an over-laxative condition.

Test cows are generally fed concentrates as many times a day as they are milked. When soaked beet pulp is fed, it seems to make the concentrate mixture a trifle more palatable if it is mixed with the beet pulp.

1108. General pointers.—It is advisable to have cows freshen in the fall when they are to be tested, for their yield of milk will be appreciably greater than if they freshen at another period. Also, the percentage of fat for the year will be slightly higher. (**1061**)

For maximum records, Holstein cows are usually milked 4 times a day and other cows at least 3 times. (**1058**) Box stalls should be provided when maximum records are desired, for this slightly increases the yield. (**1088**)

When the weather is good, test cows should be turned out for exercise in winter for an hour to a half hour a day, depending on the temperature. This aids in keeping them healthy and in developing a keen appetite. Also, it keeps their legs in condition and prevents their hoofs from growing too long.

At all times the cows should have comfortable quarters and regular care and attention, always by the same herdsman, if possible. The stable should be kept free from flies during the summer. It must always be borne in mind that only when a test cow is comfortable, contented, and in the best of health will she respond with continued production of the maximum yield of which she is capable.

There is much difference of opinion as to whether or not the useful life of a dairy cow is shortened by feeding her all the concentrates she will consume, in an effort to secure maximum production. Without much question, many cows have been injured and their future usefulness even destroyed by injudicious crowding when on test. On the other hand, by following such methods as have previously been described, experienced herdsmen are usually able to feed cows so as to secure very high records of production without apparent injury.

QUESTIONS

1. State 10 essentials in the proper feeding and care of dairy cows.
2. Why is it important that the amount of concentrates for each cow be adjusted to her actual yield of milk and fat?
3. Discuss the importance of the following for dairy cows: (a) Palatability of feeds; (b) variety in the concentrate mixture; (c) bulkiness of the concentrate mixture; (d) rations that are slightly laxative; (e) an abundance of good roughage; good hay; (f) succulent feeds.
4. Why is good pasture necessary for low-cost milk production?
5. What are the best dairy pastures in your region?
6. Discuss: (a) Supplementing short pasture; (b) feeding concentrates to cows on pasture.
7. Why is it important that cows have a dry period?
8. How would you dry off a persistent producer?
9. Discuss the feeding of cows during the dry period.
10. What is the approximate gestation period for dairy cows?
11. Discuss the feed and care of a cow at calving time; after calving.
12. What is the cause of milk fever and the usual method of treatment?
13. Describe one method recommended for preventing milk fever.
14. What is the cause of ketosis? State two methods of treatment.
15. Discuss the requirements of dairy cows for shelter and comfort.
16. What are the advantages and disadvantages of the loose-housing method?
17. Discuss fly control on the dairy farm.
18. Why is exercise important for dairy cows?
19. Discuss the frequency and order of feeding dairy cows.
20. Discuss the importance of proper milking, explaining how cows "let down" and "hold up" their milk.
21. State 4 important rules for machine milking.
22. Discuss the various items of cost in producing milk, stating the 7 classifications into which the expenses are commonly grouped.
23. Estimate the approximate cost of producing milk in your locality according to a formula, and using local prices for feeds and for man labor.
24. Discuss the effect of season of year on cost of milk production.
25. State 7 important factors in reducing the cost of milk production.
26. In what respects do the feeding and care of cows on official test differ from the ordinary methods used for economical milk production?

REFERENCES

1. Cannon and Espe, Iowa Rpt. 1931; Branton and Seath, La. Rpt. 1943; McIntyre and Ragsdale, Mo. Bul. 488; Monroe and Krauss, Ohio Bimo. Buls. 238, 239; Monroe and Livezey, Ohio Bimo. Bul. 242; see also: Jacobson, Ark. Bul. 312; Horwood and Wells, Mich. Quar. Bul., 18, 1936, No. 4; Little, Mich. Quar. Bul., 37, 1955, No. 3; N.C. Rpt. 1927.
2. Savage and Harrison, N.Y. (Cornell) Rpts. 1941, 1943.
3. Nevens, Ill., Jour. Agr. Res., 36, 1928, pp. 785–788; Moore, Huffman, and Plumb, Mich., Jour. Agr. Res., 44, 1932, pp. 789–796; Mich. Rpt. 1928–30.
4. Hoglund, Mich. Spec. Bul. 390; see also: Dunn, Del. Bul. 294; King et al., Ind. Cir. 347; Erb, McCaw, Goodwin, and Shaw, Wash. Stas. Cir. 236.
5. White and Pratt, Conn. (Storrs) Bul. 169; Atkeson, Bechtel, Shaw, and Beck, Kan. Rpt. 1938–40; Monroe and Allen, Ohio Bul. 538.
6. Becker et al., Fla. Bul. 255; La. Rpt. 1931–33; Cannon, Espe, and Goble, Iowa, Amer. Dairy Sci., Assoc., Abstr. of Papers, 29th Annual Meeting, 1933; Hayden, Monroe, Perkins, and Thatcher, Ohio Bul. 532; Monroe and Hayden, Ohio Bul. 548; U.S.D.A., Bur. of Dairy Indus., Rpt. 1945; Shepherd, Hodgson, and Sweetman, U.S.D.A., mimeo. rpt.
7. Porter, Iowa Farm Sci., 5, 1950, No. 2.
8. Petersen, Fitch, and Allen, Minn., Jour. Dairy Sci., 20, 1937, pp. 429–430; Bender, Bartlett, Tucker, and Mixner, N.J., Jour. Dairy Sci., 20, 1937, pp. 424–426; N.J. Rpt. 1937; Savage, Lepard, and Harrison, N.Y. (Cornell) Rpt. 1939; Savage, Harrison, and Taylor, N.Y. (Cornell) Rpt. 1940; Murley, N.C. Res. and Farming, 12, 1954, Nos. 3–4; Hayden, Monroe, Krauss, and Perkins, Ohio Bul. 592; Wise, LaMaster, and Mitchell, S.C. Rpt. 1943; Blosser et al., Wash. Stas. Cir. 202.
9. Fisher, Graf, Hardison, and Thompson, Va., Jour. Dairy Sci., 37, 1954, pp. 665–666.
10. Grimes, Sturkie, and Quinn, Ala. Prog. Rpt. 37; Hawkins, and Autrey, Ala., Jour. Dairy Sci., 38, 1955, p. 613; Frye, Hawkins, and Henderson, Ga., Jour. Dairy Sci., 31, 1948, pp. 897–903; Ga. Rpt. 1949; Miss. Rpts. 1952, 1953; Wylie and Neel, Tenn. Rpt. 1941; Lush, Ewing, Madux, and Wylie, Tenn. Rpt. 1948; Tenn. Rpt. 1951; Copeland, Tex. Rpt. 1943.
11. Atkeson, Shaw, and Cave, Kan., Jour. Dairy Sci., 25, 1942, pp. 779–784.
12. Del. Bul. 251; Phillips and Baker, Del. Bul. 285; King, Wilbur, and Mott, Ind. Rpts. 1946, 1948; Seath and Elliott. Ky., Jour. Dairy Sci., 33, 1950, pp. 388–389; Seath, Ky., Jour. Dairy Sci., 35, 1952, p. 502; Lush, La. Bul. 241; Archibald, Rice, Foley, and Parsons, Mass. Buls. 315, 327; Wright and Baltzer, Mich. Spec. Bul. 297; Moore, Miss. Rpts. 1925, 1926; Roberts, N.Y. (Cornell) Buls. 36, 49; Ohio Spec. Cir. 43; Kuhlman, McGilliard, and Weaver, Okla. Rpt. 1930–32; Jones and Brandt, Ore. Bul. 264; Ore. Rpt. 1922; Knodt, Penn. Bul. 515; LaMaster, Elting, and Weaver, S.C. Rpts. 1931, 1932; Bateman and Caine, Utah Bul. 239; Thompson and Holdaway, Va. Bul. 428; Knott, Hodgson, and Ellington, Wash. Bul. 295; Dawson, U.S.D.A. Leaflet 7; Moseley, Stuart, and Graves, U.S.D.A. Tech. Bul. 116.
13. Seath, Ky., Jour. Dairy Sci., 32, 1949, p. 717; Seath et al., Ky., Jour. Dairy Sci., 38, 1955, p. 612; La. Rpt. 1946; Foley, Mass., Jour. Dairy Sci., 16, 1933, pp. 407–411; N.J. Rpt. 1946; Monroe, Ohio Bul. 673; Monroe, Thatcher, and Haynes, Ohio Bul. 695.
14. Horwood and Putnam, Mich. Quar. Buls. 16, 1933, No. 1; 18, 1935, No. 1, Perkins, Ohio Bul. 548; Pratt and Davis, Ohio, Jour. Dairy Sci., 36, 1953, p. 580.
15. Dix Arnold and Becker, Fla., Jour. Dairy Sci., 19, 1936, pp. 257–266; Yapp, Ill. Rpt. 1938; Seath and Staples, La. Rpt. 1942; Dow, Me. Bul. 361; Morrow, Keener, and Hall, N.H. Tech. Bul. 86; Carroll, Utah Bul. 127; Erb, McCaw, Goodwin, and Shaw, Wash. Sta. Cir. 236; Sanders, Jour. Agr. Sci., England, 20, 1930, pp. 145–185.
16. Klein and Woodward, U.S.D.A., Jour. Dairy Sci., 26, 1943, pp. 705–713.
17. Wayne, Eckles, and Petersen, Minn., Jour. Dairy Sci., 16, 1933, pp. 69–78; Parker and Underwood, U.S.D.A. Farmers' Bul. 1470, Rev. 1954.
18. Wise, Atkeson, Caldwell, and Hughes, Kan., Jour. Anim. Sci., 5, 1946, p. 397.
19. Harrison, N.Y., unpublished data.
20. Woodward, Shepherd, and Graves, U.S.D.A. Misc. Pub. 179.
21. Hammond, Jour. Min. Agr., Great Britain, 49, 1942, pp. 3–5; see also: Boutflour, Jour. Min. Agr., Great Britain, 50, 1943, p. 306.
22. Gardner and Greenhalgh, Ill., Jour. Dairy Sci., 38, 1955, p. 618.
23. Wylie and Hinton, Tenn. Rpt. 1944.
24. Rpt. of Chief, Bur. Dairy Industry, U.S.D.A., 1951.
25. Eaton et al., Conn., Jour. Dairy Sci., 32, 1949, pp. 870–876, 919–926, 1032–1037; Gaunya and Eaton, Conn., Jour. Dairy Sci., 36, 1953, pp. 168–172; Parrish et al., Kan., Jour. Dairy Sci., 32, 1949, p. 719; Smith and Keyes, Mont. Bul. 475; Smith and Keyes, Mont., Jour. Dairy Sci., 36, 1952, pp. 1178–1181; Davis, Underbjerg, Trimberger, and Sanders, Nebr. Rpt. 1941; Keyes and Reid, Penn. Bul. 475; Dawdy and Knodt, Penn., Jour. Dairy Sci., 32, 1949, p. 725; Ackerman, West Va. Bul. 357, Part 1; Rowlands, Roy, Sears, and Thompson, England, Jour. Dairy Res., 20, 1953, pp. 16–28.
26. Dupre and King, S.C., Jour. Dairy Sci., 37, 1954, pp. 673–674.
27. Owen, Miss. Farm Res., 17, 1954, No. 6; Smith, Niedermeier, and Hansen, Wis., Jour. Dairy Sci., 31, 1948, pp. 173–177.
28. Smith and Blosser, Wis., Jour. Dairy Sci., 30, 1947, pp. 861–866.
29. Hibbs and Pounden, Ohio, Jour. Dairy Sci., 34, 1951, pp. 498–499; 38, 1955, pp. 65–72; Conrad, Hansard, Hibbs, and Patrick, Tenn. and Ohio, Jour. Anim. Sci., 14, 1955, p. 1198.
30. Boda and Cole, Cal., Jour. Anim. Sci., 10, 1951, p. 1073; Boda and Cole, Cal., Jour. Dairy Sci., 37, 1954, pp. 360–372; Boda, Cal., Jour. Dairy Sci., 39, 1956, pp. 66–72.
31. Shaw et al., Md., Jour. Dairy Sci., 35, 1952, pp. 497–498; Shaw, Hatziolos, and Chung, Md., Science, 114, 1951, pp. 574–576; Shaw, Chung, and Gessert, Md., Jour. Dairy Sci., 38, 1955, p. 611; Md. Bul. A-81.
32. Schultz, N.Y. Farm Res., 18, 1952, No. 4; Schultz, N.Y., Cornell Vet., 42, 1952, pp. 148–155; Schultz, Jour. Dairy Sci., 36, 1953,

p. 599; Schultz, N.Y., Proc. 1954 Cornell Nutr. Conf.
33. Miller, Edick, Ashby, Dawson, and Woodward, U.S.D.A. Cir. 722; see also: Wis. Bul. 470.
34. Kelley and Rupel, U.S.D.A. Tech. Bul. 591.
35. Cairns and Plummer, Me. Buls. 426, 428; Dice, N.D. Bul. 344; Bartle, S.D. Rpt. 1951.
36. Reaves and Shelor, Va. Rpt. 1950; Duffee, Einerson, and Neitzke, Wis. Bul. 488.
37. Woodward and Dawson, U.S.D.A. Farmers' Bul. 1470; Monroe, Krauss, and Hayden, Ohio Bimo. Bul. 177.
38. Longhouse and Porterfield, West Va. Cir. 91.
39. For a review of the investigations on loose-housing, see Angus and Barr, Penn., Jour. Dairy Sci., 38, 1955, pp. 391–406. Also, for the results of the most extensive investigation on the subject, see: Witzel and Heizer, Wis. Bul. 503.
40. Eaton, Ala. Rpt. 1931: Regan and Freeborn, Cal., Jour. Dairy Sci., 19, 1936, pp. 11–28; Beach and Clark, Conn. (Storrs) Bul. 32; Cannon and Richardson, Iowa Rpt. 1932; Shaw and Atkeson, Kan., Jour. Dairy Sci., 26, 1943, pp. 179–187; Eckles, Mo. Bul. 68; Grinnells, N.C. Rpts. 1930, 1931; Bartlett, N.J. Rpts. 1930, 1931; Bartlett, N.J. Agr., 15, 1933, pp. 2–3; Ohio Bul. 402; Kuhlman, McGilliard, and Weaver, Okla. Rpt. 1930–32; Searls and Snyder, Wis. Sten. Cir. 209; Searls and Daehnert, Wis. Bul. 451.
41. Hoekstra, Dicke, and Phillips, Wis. Bul. 512.
42. McCampbell, Kan., Amer. Soc. Anim. Prod., Proc. 1929; Baer, Okla. Rpt. 1924–26.
43. Bechtel, Successful Farming, 45, 1942, pp. 139, 148–151.
44. Dawson and Kopland, U.S.D.A. Cir. 830.
45. Petersen, Minn. Bul. 361; Ely and Petersen, Minn., Jour. Dairy Sci., 24, 1941, pp. 211–223; Miller and Petersen, Minn., Jour. Dairy Sci., 24, 1941, pp. 225–233; Smith and Petersen, Minn., Jour. Dairy Sci., 31, 1948, pp. 589–593; Beck and Claydon, Kan., Jour. Dairy Sci., 34, 1951, pp. 593–597; Roark, Beck, and Fryer, Kans., Jour. Dairy Sci., 35, 1952, pp. 1017–1025; Turner, Mo. Bul. 346; Swanson and Turner, Mo., Jour. Dairy Sci., 24, 1941, pp. 635–638; Dahlberg, N.Y. (Geneva) Bul. 697; Knoop and Monroe, Ohio Farm and Home Res. 266; Knodt, Reid, and Kisler, Penn., Jour. Dairy Sci., 32, 1949, pp. 637–643; Ward and Smith, Wis., Jour. Dairy Sci., 32, 1949, pp. 17–21.
46. Knodt and Petersen, Minn., Jour. Dairy Sci., 27, 1944, pp. 449–457.
47. Dahlberg, N.Y. (Geneva) Bul. 697; see also: Ragsdale and McIntyre, Mo. Bul. 477.
48. Petersen, Minn. Bul. 361 and Minn. Exten. Folder 119; Petersen, Minn., Jour. Dairy Sci., 27, 1944, pp. 433–440; Smith and Petersen, Minn., Jour. Dairy Sci., 29, 1946, pp. 45–53; Beck, Kan., Hoard's Dairyman, Oct. 10, 1952; Carter, N.H. Exten. Cir. 265; Dahlberg, N.Y. (Cornell) Exten. Bul. 606; Schultz, N.Y., Dairyman's League News, Feb. 15, 1955; Bartlett, Hilton, Little, Schalm, and Turner, Nat. Res. Council, Reprint and Cir. Series, No. 120.
49. Wilcox and Rhode, Ill. Bul. 511; Dow, Maine Bul. 429; Woodworth et al., N.H. Bul. 376; McNall and Mitchell, Wis. Bul. 421; see also: Herrmann, Stelzer, and Bowling, West Va. Bul. 268.
50. Woodward, U.S.D.A. Cir. 180.
51. Wing and Foord, N.Y. (Cornell) Bul. 213; Ellington and Knott, Wash. Bul. 229; Woll, Wis. Rpt. 1902.
52. Haecker, Minn. Bul. 130.
53. Asdell, N.Y., Jour. Dairy Sci., 34, 1951, pp. 529–535; see also: Voelker, Iowa, Jour. Dairy Sci., 34, 1951, pp. 511–512.
54. Walker, Conn., Hoard's Dairyman, Oct. 10, 1949; see also: Becker, Dix Arnold, and Spurlock, Fla. Bul. 540.
55. Cunningham, N.Y., mimeo. rpt.
56. Carter, Mich. Quar. Bul., 30, 1947, No. 2; Wilcox and Rhode, Ill. Bul. 511; Greene, N.C. Bul. 345; Lee and Cagle, Wash. Bul. 308.
57. Cunningham, N.Y., mimeo. rpt.
58. Bierly, N.Y. (Cornell) Farm Economics No. 129; see also: Wilcox and Rhode, Ill. Buls. 511, 515; Dow, Me. Bul. 483; Cunningham, N.Y. (Cornell) Exten. Bul. 641.
59. Carter, Vt. Bul. 503.
60. Harrison, N.Y., mimeo. rpt.; Eckles and Anthony, Dairy Cattle and Milk Production, 4th Ed., pp. 459–461; Petersen, Dairy Science, 2nd Ed., pp. 504–507.
61. Woodward, U.S.D.A., Jour. Dairy Sci., 10, 1927, pp. 283–291.
62. Bender, N.J. Cir. 302.
63. Nevens, Ill. Cir. 372.

CHAPTER XXVII

RAISING DAIRY CATTLE

I. Nutrients Required for Growth of Dairy Cattle

1109. Importance of proper raising of well-bred heifers.—It has been emphasized previously that to secure a good net income from dairying, the first necessity is a herd of high-producing cows. The most certain method of developing a high-yielding herd is by replacing the poor producers with well-bred, home-raised heifers of greater productive capacity.

Such heifers should be from the best cows in the herd; they should be sired by a purebred bull which has been selected for ability to transmit high production; and they must be so raised that they will have a large capacity for converting feed into milk. Even when well fed, many cows are unable to develop their full inherited capacity for milk production, because they were stunted during growth by a lack of feed or by nutritive deficiencies.

The dairyman who follows the plan of purchasing his replacements will often be badly disappointed, even if he is careful to buy only heifers or cows whose appearance is promising. The farmer from whom he buys will naturally desire to retain for his own herd the heifers out of his very best cows. In addition to the difficulty of buying animals that will prove profitable, there is also much more danger of introducing disease when replacements are purchased.

1110. Nutrient requirements.—Before discussing the various rations suitable for raising dairy cattle, we should have clearly in mind the nutrient requirements for growth, which have been considered in Chapter IX. In raising dairy cattle especial attention must be given to providing: (1) Plenty of protein; (2) protein of satisfactory quality; (3) enough total digestible nutrients to permit normal growth; (4) sufficient minerals, especially calcium, phosphorus, and common salt; and (5) liberal amounts of vitamins. These requirements are discussed in detail on the following pages.[1]

In the Morrison feeding standards, given in Appendix Table III, recommendations are made concerning the amounts of dry matter, digestible protein, total digestible nutrients, calcium, phosphorus and carotene that should be supplied young dairy cattle at various stages of growth. These recommendations are based on the results of the experiments that have been conducted, especially by American experiment stations, to determine the requirements for the normal development of young dairy cattle.

At birth, a calf is actually not a ruminant, for the rumen has developed but little. Its needs for protein of high quality and for B-complex vitamins are therefore similar to those of pigs or chicks. These requirements are amply met when the calf is fed a normal amount of milk for at least 6 to 9 weeks and is supplied with good roughage. By that time the rumen will have developed sufficiently so that the calf has become a real ruminant.[2] Then ample supplies of the B-complex vitamins are synthesized in the fermentations that take place in the rumen, and also the quality of protein is of much less importance, if ample good roughage is fed. (**209, 112**)

When calves are weaned at only a few days of age and are fed a milk replacer, instead of milk, high-quality protein and B-complex vitamins must be provided in the replacer. (**1142**) The rumen develops more rapidly in calves if they are supplied with plenty of suitable hay as soon as they will eat it.[3] In

some cases calves are ruminating at 2 to 3 weeks of age.

1111. Amount of protein required.—Like other young animals, calves need a relatively large proportion of protein in their rations to provide for the rapid growth of their protein tissues. The proportion of protein required becomes less as the animal grows older, because less of the gain then consists of protein. (259)

But little experimental information is available concerning the minimum amounts of protein needed by dairy calves up to the age of 4 months. Even for older animals the data are not very extensive. The recommendations in the Morrison standards are based on a study of the available information, including recent New York experiments and New Hampshire and English investigations.[4]

1112. Quality of protein.—The kind or quality of protein in the ration is undoubtedly important for very young calves, because the paunch, or rumen, has not yet developed much. (112) However, during this period calves usually receive sufficient milk to insure an ample supply of good-quality protein.

By the time a calf is 3 or 4 weeks of age, it is eating some hay and the rumen has developed enough for the bacterial action to occur, which is characteristic of digestion in ruminants. The quality of protein in the ration then becomes of much less importance, as has been pointed out in Chapter V.

When calves are fed a reasonable amount of whole milk or skimmilk until they are 4 or 5 months of age, no special attention need be paid to the quality of protein furnished by the rest of the ration. As is shown later, an excellent ration for calves after 3 to 4 weeks of age is merely skimmilk plus cereal grain and good legume hay.

When milk feeding is discontinued at 6 to 9 weeks of age, as in the "calf starter" method which is discussed later, the quality of protein in the calf starter is of importance until the calves are 3 or 4 months old. However, good results are secured with calf starters which contain no animal protein, but in which a considerable part of the protein is supplied by soybean oil meal, a feed that also furnishes protein of high quality. (1141)

If calves are weaned at only a few days of age and fed a milk replacer, the quality of protein is very important.[5] (1142)

1113. Total digestible nutrients.—Since the rumen of a young calf is not yet well developed, it must be fed chiefly on milk or on concentrates high in digestible nutrients and low in fiber. As the calf grows older, it can utilize more and more roughage; until after 10 months of age the ration may even consist entirely of roughage, if it is of excellent quality.

The amounts of total digestible nutrients advised in the revised Morrison feeding standards for young dairy cattle at various stages of growth are based on investigations conducted at several experiment stations, especially recent Vermont experiments and studies at the Minnesota, Missouri, and New Hampshire Stations.[6] It will be noted that the amount of total digestible nutrients required per head daily increases gradually from 1.8 to 2.2 lbs. at 100 lbs. live weight up to 10.0 to 12.0 lbs. at 1,000 lbs. live weight.

1114. Fat. — Recent experiments have proved that young calves need a certain amount of fat in their diet.[7] Calves fed a fat-free synthetic ration from a few days of age could not grow and finally died. They showed various symptoms of fat deficiency—rough hair coat, partial loss of hair, leg-weakness, muscular twitches, diarrhea, and emaciation. Only 1 to 2 per cent of a suitable fat prevented the trouble. The deficiency was not a lack of an essential fatty acid, for it was prevented by adding a hydrogenated fat, in which the unsaturated fats had all been changed to saturated fats. (133)

This need for fat is fully met when calves are fed whole milk for 6 to 9 weeks in the usual calf-starter method. However, it must be borne in mind in making up a milk replacer for very young calves, or when whole milk is replaced

by skimmilk or reconstituted skimmilk at too early an age.

1115. Minerals.—If growing dairy cattle are fed rations that are otherwise satisfactory, there will commonly be no deficiency of any mineral except *common salt.* As soon as calves begin to eat concentrates, salt should be provided where they can take what they wish. Under certain conditions there may also be a deficiency of *phosphorus* or of *calcium,* as is pointed out in the following article.

Iodine is furnished in ample amounts by the ordinary rations fed growing cattle in most districts. If any calves at birth show evidence of goiter, or "big neck," this should be prevented in the future by the use of iodized salt or some other iodine supplement, as shown in Chapter VI. (**170**) In an area where there is a deficiency of cobalt or one of the other trace minerals, the lack should be corrected as shown in Chapter VI. In other regions there is no benefit from using a trace-mineral supplement.[8]

If calves are raised too largely on milk, without much roughage, anemia may develop because of the deficiency of iron and copper.[9] (**174**) This may be prevented by providing the small amounts of these minerals needed.

1116. Calcium and phosphorus.—If calves are fed a normal amount of whole milk or skimmilk, they will receive an ample amount of both calcium and phosphorus. Calves and heifers will get an abundance of calcium when they are fed plenty of legume hay or mixed hay high in legumes. Even when they get only non-legume roughage, such as grass hay or grass pasturage, there will generally be no lack of calcium, unless the soil on which the forage is raised is unusually low in calcium.[10] If there is any possibility of a deficiency, calcium can be provided cheaply by ground limestone or some other calcium supplement. (**157**)

There will be no lack of phosphorus, after calves are weaned from milk, if they are fed 2 to 3 lbs. per head daily of a concentrate mixture containing 10 to 20 per cent of such phosphorus-rich protein supplements as wheat bran, wheat middlings, linseed meal, or cottonseed meal.

When growing cattle are fed only cereal grains and hay, with or without corn or sorghum silage, there may be a serious lack of phosphorus if the soil on which the roughage is grown is deficient in this mineral. In such cases bone meal or some other safe phosphorus supplement should be provided, as advised in Chapter VI. (**158**)

The amounts of calcium and phosphorus advised per head daily for young dairy cattle at various stages of growth are stated in Appendix Table III. These recommendations are based on recent investigations at the Vermont Station and on Massachusetts, Michigan, Oregon, and West Virginia studies.[11]

It will be noted, for example, that allowances of 13 grams of calcium and 12 grams of phosphorus are recommended per head daily for an 800-lb. growing animal. So long as sufficient calcium and phosphorus are provided, the proportion between the amounts of these minerals (the calcium-phosphorus ratio) can vary considerably for cattle, without producing any detrimental results. (**152**)

1117. Vitamin A or carotene requirements.—Dairy calves undoubtedly suffer more often from a lack of vitamin A than from a deficiency of any other vitamin. A serious lack of it will produce disaster even in animals 1 to 2 years old.[12] However, the vitamin A needs are readily met when calves are raised according to one of the methods described later in this chapter.

It has been pointed out previously that young animals are born with only a very small supply of vitamin A or carotene in their bodies. (**270**) They are therefore dependent chiefly on the amounts they receive in their food. Fortunately, the colostrum from properly fed cows is very much higher than normal milk in vitamin A value. Indeed, it may have 100 times as much as normal milk. The high vitamin A value of colostrum is one of the chief reasons why it is so important for calves to receive a normal amount of it after birth and for the first 3 days.

Because normal whole milk from well-fed cows is rich in vitamin A value, there will commonly be no lack of vitamin A during the period when a calf is fed the usual amount of whole milk. However, in order to insure plenty of vitamin A and also to furnish other vitamins, it is important, as is emphasized later, to supply excellent legume or mixed hay just as soon as the calf will eat any of it. (1133)

HIGH-QUALITY HAY IMPORTANT FOR CALVES

To insure a plentiful supply of vitamins, it is essential that calves have excellent legume or mixed hay as soon as they will eat it. A "calf starter" is also being fed this calf in the feed box. (From New York State College of Agriculture, Cornell University.)

Though skimmilk is very low in vitamin A value, there is usually no deficiency of vitamin A when calves are changed entirely from whole milk to skimmilk by 3 or 4 weeks of age, if care is taken to let them have plenty of first-rate hay. If whole milk is discontinued even earlier, or if the hay is not of good quality, it is important to feed a vitamin A supplement, such as cod-liver oil concentrate, or to use a calf starter or a milk replacer that is reinforced with such a vitamin supplement.[13] New Mexico experiments show, however, that if calves are fed plenty of good-quality legume hay, there is no benefit from supplying a vitamin A supplement when the feeding of whole milk is discontinued at 30 days of age.[14]

If a cow is milked a few days before calving (prepartum milking) in an attempt to reduce congestion of the udder, the colostrum will be secreted mostly before she calves.[15] (1084) Unless the calf can be fed colostrum from another cow or stored colostrum, a vitamin supplement should be added to the milk.

Calves can use vitamin A much more efficiently than they can carotene, especially at an early age. In Connecticut studies it required 5 or more times as much carotene as of vitamin A to prevent symptoms of vitamin A deficiency.[16] However, providing plenty of carotene-rich hay as soon as they will eat it will meet their needs. Since feeds of plant origin supply carotene and not vitamin A, the vitamin A requirements of cattle are commonly stated in terms of carotene.

A special committee of the National

Research Council has recommended in its report on *Recommended Nutrient Allowances for Dairy Cattle* that growing dairy cattle receive 4 milligrams of carotene (beta-carotene) daily per 100 lbs. live weight.[17] To insure an adequate supply under all conditions, the amount was placed fully twice as high as the minimum that has been shown to be necessary to prevent symptoms of vitamin A deficiency under controlled experimental conditions.[18]

Considerably more carotene is needed in winter than in summer, and the difference does not seem to be due chiefly to the temperature.[19] Guernseys and Jerseys require slightly more carotene per 100 lbs. live weight than do Holsteins or Ayrshires.

To secure thrifty calves that start out life with a normal, though limited, supply of vitamin A, it is very important that the cows receive plenty of vitamin A value during pregnancy. As has been emphasized previously, the results are disastrous when cows are fed for long periods on rations seriously deficient in vitamin A. (**564, 1042**) Not only are the calves often born dead or very weak, but also the milk is so deficient in vitamin A that even calves from well-fed cows cannot be raised on it without a vitamin A supplement.

Feeding a cow during pregnancy a ration having plenty of carotene considerably increases the vitamin A content of the colostrum and later milk. It also insures a normal supply of vitamin A in the body of the calf at birth. As shown previously, the store of vitamin A in the calf at birth and the amount of the vitamin in the colostrum can be increased still more by feeding a concentrated vitamin A supplement to the cow for some weeks previous to calving. (**270**)

1118. Vitamin D requirements.—Calves must have an ample supply of vitamin D, for a lack will cause serious trouble from rickets.[20] The symptoms of this nutritional disease have been described previously. (**153**) However, there will ordinarily be no lack of vitamin D if care is taken to provide good-quality field-cured legume or mixed hay as soon as the calves will eat it. Since whole milk is not rich in this vitamin, even a liberal amount of it may not furnish enough to protect calves against rickets. Fortunately, calves will begin to eat hay at 2 or 3 weeks of age, and if then supplied with good hay, they will soon eat sufficient to furnish the needed amount of the vitamin.

In Michigan experiments even 1 lb. of field-cured U.S. No. 1 alfalfa hay or 2 lbs. of No. 2 timothy hay per head daily provided enough vitamin D to prevent rickets in calves, when it was the only source of the vitamin.[21] In Vermont experiments that have been mentioned previously, calves and heifers fed poor-quality, late-cut timothy hay as the only hay and not on pasture in summer showed no evidences of a vitamin D deficiency. (**1047**) Adding a vitamin A and D supplement to the ration with this poor hay increased the gains, but was of little benefit for other animals fed good hay.

Since sunlight that has not passed through ordinary window glass has an anti-rachitic effect, exposure of calves to sufficient direct sunlight prevents rickets. (**201**) Winter sunlight in the northern states has much less anti-rachitic effect than summer sunlight, and also young dairy calves are not generally turned outdoors at all in cold weather. However, if calves are supplied with plenty of good-quality sun-cured hay, they usually receive enough vitamin D, even if in the stable all the time and exposed only to sunlight that has passed through window glass.[22] In experiments by the United States Department of Agriculture, even barn-dried hay or wilted hay-crop silage prevented rickets in dairy calves not exposed to any sunlight. (**204**)

If a very liberal amount of concentrates is fed to calves, especially to those also getting milk, they may fail to eat enough hay to prevent rickets.[23] Also, sometimes calves that are making excellent growth develop mild cases of rickets, showing particularly the characteristic sag in the back, just behind the shoulders. Such animals are growing rap-

idly in skeleton, and therefore need especially liberal amounts of vitamin D.

To guard against a possible vitamin D deficiency, it is a good plan to include a suitable amount of a vitamin D supplement in calf starters used in the calf-starter method of raising calves, and also in milk replacers. (1141, 1142)

The special committee of the National Research Council in the report on Recommended Nutrient Allowances for Dairy Cattle, which has been mentioned previously, recommends an allowance of 400 International Units of vitamin D per 100 lbs. live weight for dairy calves.[17] This allowance evidently provides a considerable margin of safety, for experiments by the United States Department of Agriculture indicate that the minimum requirement of young dairy calves for vitamin D in the form of alfalfa hay is only 150 to 200 International Units per 100 lbs. live weight.[24]

1119. Other vitamins.—Generally, there is no deficiency of B-complex vitamins when dairy calves are raised by one of the usual methods. As soon as the paunch, or rumen, becomes sufficiently developed for normal ruminant digestion to occur, the B-complex vitamins are synthesized in the rumen by bacterial action.[25] (209) Before this, these vitamins are supplied by the milk the calf is generally fed.

If calves are weaned from milk at only a few days of age, B-complex vitamin supplements should be included in the milk replacer, if it does not contain a considerable proportion of dried skimmilk and other dairy by-products. (1142)

In most experiments there has been no benefit from adding to a normal ration for dairy calves, either B-complex vitamins or yeast, which is rich in these vitamins.[26] Ordinarily, a deficiency of B-complex vitamins can be produced only when calves are raised on an abnormal synthetic ration that includes no ordinary roughage.[27] In experiments in which calves have been fed such rations, it has been proved that they require thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, and vitamin B_{12}.[28] All these vitamins are provided amply in the ordinary methods of raising dairy calves.

Under usual conditions ascorbic acid, vitamin C, is of no importance in raising dairy cattle. (224) Synthesis of this vitamin in the body begins by the time a calf is 2 or 3 weeks old, and there is generally a sufficient store in the body at birth to meet the needs up to this time. Calves have been raised successfully on a ration so lacking in ascorbic acid that it would produce scurvy in guinea pigs within a month.[29]

If calves are fed the usual rations, with plenty of good roughage, there is no lack of vitamin E. (1040)

1120. Vitamin pills or capsules.—It has been advocated that, in herds where the losses from scours or other diseases have been serious, the calves be given soon after birth and during the first few weeks vitamin pills or capsules which supply vitamin A, vitamin D, niacin, and in some cases other B-complex vitamins.[30] However, in extensive experiments in several states and with great numbers of calves, the use of such vitamin pills or capsules has not been beneficial.[31] They have not lessened scours or other diseases, or improved the appearance or condition of the calves.

It has been pointed out earlier in this chapter that when the feeding of whole milk is discontinued at an extremely early age, it is important to feed a vitamin A supplement. (1117) Also, under certain conditions, the use of a vitamin D supplement is advisable. However, there is generally no need of using such vitamin supplements when calves are fed the usual amount of whole milk and supplied with good-quality hay at an early age.[32]

1121. Antibiotic feed supplements.—Since the discovery was made that the feeding of certain antibiotics increased the growth of some young animals, scores of experiments have been conducted by the experiment stations to determine the effects of antibiotic feed supplements on dairy calves.[33] (966) Most of these investigations have been with aureomycin

feed supplements or with pure aureomycin (chlortetracycline).

In the great majority of the experiments, but not all, the addition of an aureomycin supplement to the ration has increased the rate of gain of dairy calves decidedly. It has generally reduced the cases of scours and other infectious diseases, and improved the thriftiness and the appearance of the calves. These effects are greater in herds where there has been much trouble from disease. However, an antibiotic supplement is no cure-all, and it does not give protection against unsanitary and slovenly practices.

The effect of the antibiotic supplement is the greatest during the first 7 weeks of life, and there is little effect after calves are 6 months old. After this age, heifers that have not received an antibiotic supplement previously will probably tend to grow faster than those which have had the supplement, and by the time they freshen there will likely be no appreciable difference in size. Therefore, in raising replacement dairy heifers the chief advantage from feeding an antibiotic supplement when they are calves is the lessening of scours and other diseases.

An antibiotic supplement has the most effect when it is added to the milk or milk replacer during the first few weeks. If this is not done, there may be a slight benefit from including an antibiotic supplement in the calf starter.

Aureomycin and terramycin feed supplements generally stimulate the appetite so that calves eat more feed. In some experiments less feed has been required per 100 lbs. gain with the antibiotic, but in a greater number of trials the feed efficiency has not been increased. The use of an antibiotic supplement does not apparently increase the digestibility of the ration in most cases.

In some experiments terramycin has been as effective as aureomycin, but not in others. Bacitracin has not equalled aureomycin in effectiveness, and penicillin, and chloromycetin have been ineffective. The results with streptomycin have differed greatly. Feeding 30 milligrams of aureomycin or terramycin per calf daily has generally been as beneficial as a higher level.

1122. Surfactants; arsonic supplements.—Only a few experiments have been reported thus far in which a *surfactant,* or surface-active agent, has been used to supplement a ration for young calves.[34] (967) Except in one test, a surfactant has been less effective than aureomycin in increasing growth and preventing scours, or it has not been beneficial at all.

The data are yet too limited to show whether *arsonic supplements* (arsanilic acid or other arsonic acid derivatives) are as effective as an antibiotic for young calves.[35]

1123. Cud inoculation.—When a calf is only a few days of age, its rumen is developed but little, and the characteristic cellulose-digesting bacteria found in the rumen of older cattle are not present in appreciable amounts. If the calf is in contact with older cattle, the rumen soon becomes inoculated with these organisms, perhaps by eating feed which has been slobbered on by these animals while chewing the cud.

Pounden and Hibbs of the Ohio Station believe, as a result of their studies, that when calves are separated from their dams shortly after birth and kept in individual pens, it is desirable to inoculate them by placing in the back of the mouth fresh cud material from healthy older cattle.[36] They advise giving the treatment once a week for the first few weeks. The cud material can be secured from the mouth of a ruminating cow. In their tests the health of calves thus inoculated was improved. Frozen or dried rumen contents or dry commercial preparations were not a satisfactory substitute for the fresh cud material.[37]

In trials at other experiment stations there has been no benefit or only very slight benefit from inoculating calves with fresh cud material.[38]

1124. Water.—Calves over 8 weeks of age should have plenty of fresh water at least twice a day, even when they are fed normal amounts of milk. A lack of water may seriously reduce the rate of

growth.[39] Up to 8 weeks of age, calves will drink but little water if they have a liberal amount of milk, and there is then probably little advantage from supplying water in addition during this period.

After this, they will drink rapidly increasing amounts of water, and should be furnished it. It is especially important to provide plenty of water when calves are raised on a minimum amount of milk or on dry calf starters.

For a young calf it is probably best to give it lukewarm water twice a day, a couple of hours after it is fed milk, instead of having a drinking cup in the pen. With a drinking cup, the calf may go to it after the milk is finished and drink so much water as to cause scours.

In Idaho trials, calves fed 12 to 16 lbs. of skimmilk a day to 6 months of age drank the following amounts of water per day: At 4 weeks of age, 0.07 lb;. 6 weeks, 0.5 lb.; 8 weeks, 2.2 lbs.; 10 weeks, 4.3 lbs.; 12 weeks, 6.6 lbs.; 16 weeks, 12.9 lbs.; 20 weeks, 18.0 lbs.; and 26 weeks, 33.4 lbs.[40] In a Wisconsin trial calves raised on a dry calf starter and hay, with only 400 lbs. of whole milk the first few weeks, drank about 4,900 lbs. of water per calf up to 6 months of age.[39]

II. Raising Dairy Calves

1125. Precautions in raising calves.—Probably about 20 per cent of the calves born in our chief dairy districts die from disease, especially calf scours and pneumonia. To reduce these losses and raise vigorous, thrifty calves, careful attention to the following points is necessary:

As has been emphasized in the previous chapter it is important first that the cows be properly fed prior to calving, so that the calves are thrifty at the outset and so that the colostrum and later milk have a high vitamin content.

The cows should calve in a well-cleaned and disinfected maternity stall. To prevent the spread of disease, each calf should be kept in a separate calf pen for the first several weeks. The pen should be kept clean and well bedded, and should be thoroughly disinfected before a new calf is put in it. The walls between the pens should preferably be solid so there can be no contact of the calves.

The calves should be fed at regular intervals, and any change in the feed should be made gradually. Water and salt should be supplied. In summer, shade should be provided for calves on pasture. The feeder should watch for any signs of scours and at once take suitable measures to overcome the trouble.

White scours, or virulent scours, which usually occurs within 72 hours after birth, causes severe losses in some herds. This is a virus disease, which is readily transmitted by exposure of new-born calves to infected calves or contaminated pens.[41] A preventive, recently developed by Link of the Wisconsin Station, seems to be effective in herds where the trouble has been serious.[42] This product, which is now made commercially, contains dried irradiated blood serum, vitamin K, and predigested milk solids.

1126. Housing.—The quarters for calves should be well ventilated and lighted and drafts must be avoided. Where trouble from disease has been serious in large herds, it is a good plan to use small calf barns with only a few individual pens, instead of a large calf barn. Sometimes elevated floors, made of wire screen, are used in the individual pens to keep the calves drier and cleaner.[43]

In the southern states a method of housing young calves in small individual pens with no floors, placed on pasture, helps prevent disease and infection with parasites. One-half of the pen is roofed and in cold weather is enclosed on three sides. The pens are moved once a week to fresh spots of pasture. In Alabama tests excellent results have been secured by this method.[44]

Even in the northern states calves can be successfully raised in open sheds, if they are kept dry with plenty of bedding and are protected from drafts.[45] More feed will be required than in warmer quarters, but there is apt to be less trouble from disease.

1127. The new-born calf.—The care of the cow at calving time and the care of the new-born calf have been considered in the preceding chapter. (1084) A new-born calf is very sensitive to the treatment it receives and has but little resistance to certain diseases. Great care is therefore necessary to prevent infections, as has been emphasized in the previous discussion. The calf should always be protected from drafts and from cold and dampness, and the navel should be disinfected with tincture of iodine soon after birth.

If the cow's udder is soiled, it should be washed with soap and water and dried with a clean cloth before the calf nurses. The calf should nurse within an hour after birth, and if it is weak and fails to nurse, it should be helped patiently to get its first meal.

It is very important that the calf get the colostrum, or first milk, immediately after birth. (270) This protects the new-born calf against diseases, especially of the digestive system. Also, its very high vitamin A content is of great importance, for the calf is born with a very small store of the vitamin.

If for any reason a calf cannot receive colostrum milk, a vitamin A supplement should be administered and a colostrum substitute should be used, such as are now available. For this purpose an egg-white emulsion may be used, prepared by mixing the whites of 6 eggs with fresh cow's milk for the first feeding.[46] For the following feedings, one less egg is used each time.

1128. Utilizing surplus colostrum.—A good dairy cow generally produces much more colostrum than her own calf can consume. The surplus is often wasted on dairy farms. Experiments have proved that the gains of calves are increased when colostrum feeding is continued for a longer period than normal, by giving a calf other colostrum than from its dam.[47] When surplus colostrum is available, it can replace part of the milk for any of the calves without causing scours.

Surplus colostrum may be stored for considerable periods by freezing it, which can often be done easily outdoors in winter in the northern states.

1129. Starting the calf on whole milk.—No matter what method of feeding is followed later, a calf should receive whole milk in normal amounts for at least 2 weeks, and preferably for 3 or 4 weeks or more if it is especially valuable or if it is not strong. For very young calves there is no satisfactory substitute for milk.

Hunger is a great aid in teaching a calf to drink, and therefore the first lesson had better be postponed until 10 to 12 hours after it is separated from its dam. One should be patient with the calf and remember that its instinct is to seek its food at a level above its nose and not down in a pail, and also that it frequently bunts the udder of its dam while nursing, thus massaging it. The calf can not be blamed if it follows these instincts for a time.

After putting a quart of fresh, warm milk in a clean pail, one is ready for the first lesson. A common method is to back the calf into a corner and stand astride it to hold it fast. Then hold the pail in one hand, dip the fingers of the other hand in the milk, and while the calf is sucking the fingers, bring its nose down into the milk. Then gradually withdraw the fingers, holding them at the end of the nose for a little while. Above all, be patient in repeating the process as needed. The calf pails in which milk is fed must be kept scrupulously clean and should be sterilized, if possible.

The young calf should be fed sparingly, for there is much more danger of overfeeding the first few days than of underfeeding. For the first day or two 5 or 6 lbs. of milk daily is a safe allowance for an average calf, with 8 lbs. as a maximum for a large, lusty one. This allowance should be divided between 2 or 3 feedings and the amount of each should be measured or weighed and not estimated. The milk should be fed as fresh as possible and at a temperature of 90° to 100° F., determined by a thermometer, instead of guessing at it. Feeding 3 times a day is slightly better for the calf during the first week or so and is advisable if the cows are milked thrice daily.

If possible, it is a good plan to feed the calf milk from its dam for the first few days, unless the milk is very high in fat. In this case it may be wise to use milk from a low-testing cow for a week or two, or else to add warm skimmilk or water to lower the fat percentage.

The allowance of milk should be gradually increased as the calf grows older, if it is thriving. Overfeeding, the cause of much trouble in calf rearing, should be avoided at all times. A safe plan is to keep the calf a little hungry. A good rule is to feed 1 lb. of whole milk daily per 10 lbs. live weight. Weak or sickly calves should be fed less, and even a large and vigorous calf should not be fed more than 12 lbs. a day. In case of indigestion or scours, the allowance should immediately be cut in half until the calf recovers.

Calves not in individual pens should be confined in stanchions for a time after the milk is drunk, until they consume their concentrate allowance and overcome the desire to suck each other's ears or udders. If this is not done, the shape of the udder may be injured or a heifer may later persist in sucking herself or other cows.

In some experiments calves have been less apt to suffer from digestive upsets when fed milk by means of "nipple pails" than when it is fed in ordinary pails.[48] In other trials there has been little difference in the results with nipple pails and other pails.[49] The calf gets milk more slowly from the nipple pail by sucking on the nipple, and cannot gulp the milk down, as from an ordinary pail. The advantages of nipple pails are offset more or less by the fact that more care may be necessary in cleaning them, to keep them in sanitary condition.

1130. Various methods of raising calves.—If one wishes to raise dairy calves so they will make maximum growth, regardless of expense, there is no better way than to continue the feeding of a considerable amount of whole milk for 5 or 6 months or longer. On account of the expense, however, relatively few dairy calves are raised on whole milk, except when they are reared by the "nurse-cow method." (1139) After calves have a good start on whole milk, they may be raised successfully by the several different methods described in detail in this chapter.

1131. Feeding grain and other concentrates.—When a calf is 1 to 2 weeks old, it should be taught to eat concentrates. Though certain mixtures are especially popular for feeding young calves, almost any mixture of the farm grains is satisfactory, or even a single grain. If the calf gets plenty of whole milk, skimmilk, or buttermilk, it will receive sufficient protein in the milk. Adding a small amount of such a feed as wheat bran or linseed meal to grain will usually make the mixture more palatable to calves, and therefore may be advisable, merely from this standpoint.

Such mixtures as the following are excellent for calves fed milk:

(1) Corn, 30 to 40 lbs.; oats, 30 lbs.; wheat bran, 10 to 20 lbs.; linseed meal, 10 lbs.

(2) Equal weights of corn or barley and of oats or wheat bran.

(3) Corn, 30 lbs.; wheat bran, 10 lbs.

(4) Corn, 30 lbs.; linseed meal, 5 lbs.

(5) Corn, 40 lbs.; wheat bran, 10 lbs.; linseed meal or soybean oil meal, 10 lbs.

In these mixtures other grains, such as ground barley, ground wheat, or ground grain sorghum, may be substituted for the corn and oats. Rye is less palatable and should not form too large a part of a mixture for calves. Dried beet pulp may be used as a substitute for part of the grain for calves 2 to 3 months old or more.

A limited amount of cane molasses can be used in place of grain for calves, but too large a proportion is apt to cause scours. In Louisiana trials the results were satisfactory when only 1 to 2 ounces of molasses per head daily were mixed with the concentrates at the start, and the amount of molasses increased very gradually until molasses formed one-half the concentrates when the calves were 5 months old.[50]

Other protein supplements may be used in place of linseed meal, soybean oil meal, or wheat bran in these mixtures. Standard wheat middlings or flour wheat middlings are good substitutes for wheat bran. Red dog flour is often used in mixtures for calves raised on a minimum of milk, because of its high digestibility.

Corn gluten feed, corn gluten meal, and peanut oil meal are satisfactory protein-rich supplements. Cottonseed meal may be used in the limited amounts stated previously. (813)

plenty of milk or skimmilk. In Wisconsin trials calves fed ground corn as the only concentrate with skimmilk and legume hay were thrifty and made good gains.[51] Others fed a mixture of corn, oats, wheat-bran, and linseed meal gained a trifle more, but the feed cost was higher.

Calves chew corn or oats thoroughly up to an age of 6 to 9 months and, after they have learned to eat concentrates, show a preference for the whole grain. Therefore, the whole grain gives as good or better results than when ground.[52]

Calves Need a Liberal Amount of Concentrates

To produce rapid and thrifty growth, calves must have a liberal amount of concentrates. The percentage of protein needed in the concentrate mixture will depend on whether or not they are receiving considerable whole milk or skimmilk.

These mixtures all provide sufficient protein for calves raised on plenty of milk (whole milk, skimmilk, or buttermilk). If the amount of milk is limited and especially if calves are weaned at an early age and raised on concentrates and hay alone, the mixture must contain much more protein. Also, a larger proportion of protein supplements is required when calves are raised on whey. Suitable mixtures to use under these various methods of feeding are stated later in the discussions of these methods.

Whole or ground oats are often used as the only concentrate for calves fed

When such a mixture as corn and linseed meal is fed, the corn is often ground to prevent the linseed meal from separating out. After calves are 6 to 9 months old, they chew grain less thoroughly, and corn and oats should then be ground. Such hard grains as barley, wheat, and the grain sorghums should always be ground. Coarse grinding is preferable to fine grinding for calves.

1132. Feeding concentrates.—The calf can be taught to eat the grain mixture by putting a handful or less in the bottom of the pail after it has finished drinking its milk. Some add the mixture

to the milk, but this is inadvisable, as the meal is then chewed less thoroughly. The calf that is backward may be taught to eat the mixture by rubbing some on its muzzle when it is through drinking milk, or by putting a little in its mouth. After the calf has learned to eat grain, the mixture should be fed dry in a suitable feed box or in the manger.

Until the calf is 2 to 3 months old, it may eat as much of the mixture as it desires, a supply being kept before it in a feed box. Care should be taken to clean the box out regularly.

Older calves fed a liberal allowance of skimmilk may be allowed up to 4 lbs. of the grain mixture a day, and those raised on calf meal, up to 5 lbs. a day. If the calves begin to eat more than this, the proper amount should be hand-fed twice daily, instead of letting them have all they will eat. Otherwise, they will not eat enough hay, and also the feed cost will be too high.

1133. Importance of plenty of good hay for calves.—It is very important that calves have hay of first-rate quality as soon as they will eat it. Green-colored, sun-cured hay is not only high in vitamin A value, but it is also the richest source of vitamin D among common feeds. In addition, it has a good content of B-complex vitamins. Supplying plenty of such hay will therefore prevent any deficiency of vitamins.

Providing ample high-quality hay also develops the calf's rumen more rapidly and hastens the establishment of mature-type cellulose-digesting bacteria.[53] In addition, it prevents anemia, which may occur in calves fed too largely on milk or milk and concentrates.[54]

At about 2 weeks of age, a handful of the hay should be placed each day where the calf can get it. Little will be eaten at first, but even this may be important in preventing rickets and other troubles. As the calf grows and its rumen develops, more hay will be eaten, until at 6 months of age it should be eating 3 to 5 lbs. a day. The amount of hay eaten per 100 lbs. live weight usually increases up to about a year of age.

The best way to feed hay to calves is in a slatted rack. All uneaten hay should be removed daily and fed to other stock, for calves do not like hay which has been picked over.

It is never safe to attempt to raise calves without plenty of good hay or other good roughage. As has been shown earlier, attempts to raise calves on milk alone or on milk and grain without roughage have ended in failure. (253)

Occasionally, a calf will show an abnormal appetite and will eat the bedding or will gorge on an undue amount of hay, which may result in a serious digestive disturbance. Fortunately, this rarely happens with healthy calves. Some breeders keep muzzles at hand and if a calf shows such a tendency, they muzzle it for the first month, except at the time it is fed milk and concentrates. The use of muzzles on all calves for the first month has been advocated as a protection against such trouble, but on account of the nutritive benefits that young calves secure from good hay, this practice seems unwise, except perhaps where there have been severe losses from calf diseases.

1134. Legume hay excels for calves.—Fine-stemmed, leafy legume hay is the best for calves, because of its high content of protein, calcium, and vitamins. Excellent quality mixed legume-and-grass hay that is high in proportion of legumes ranks next.

Occasionally, young calves may eat so much of excellent legume hay that its laxative effect may cause them to scour. This can be avoided by limiting the amount of hay or by starting them on mixed legume-and-grass hay. In experiments during 6 years by the author and associates at the Wisconsin Station, calves were allowed access to red clover hay from the start with uniform success, and in later trials were fed alfalfa with like good results.[55] In New York trials, calves fed U.S. No. 1 alfalfa hay ate more hay and made slightly more rapid growth than others fed mixed hay of similar quality.[56] Probably many cases of scours have been attributed to the laxative effect of legume hay when some other factor has really been responsible.

In general, the leafier that hay is,

the higher will be its value for calves. Second-cutting clover or alfalfa hay is therefore preferred to first-cutting. Good-quality lespedeza hay, soybean hay, cowpea hay, or mixed hay high in legumes are all very satisfactory for calves.

If no good legume or mixed hay is available for the calves, early-cut, well-cured grass hay can be used satisfactorily. In Oklahoma experiments calves raised by the calf-starter method with good prairie hay as the roughage made normal gains, although somewhat less than on alfalfa.[57] In a New York trial calves fed U.S. No. 1 timothy hay ate less hay and consumed more concentrates than others fed alfalfa, but even then grew less rapidly.[56]

That good growth can be secured on a very small amount of concentrates when heifers have plenty of first-class legume hay is shown by recent trials of the United States Department of Agriculture.[58] Heifers fed all they would eat of excellent alfalfa hay, made normal growth to 2 years of age when raised by the calf-starter method, with no milk after they were 60 days old and no concentrates at all after 8 to 9 months of age. The heifers received a total of only about 560 lbs. of concentrates per head, which is far less than is fed by most dairymen.

The importance of good hay is further shown by extensive Vermont experiments in which good grass hay was compared with hay from similar fields cut a month later.[59] When a year of age, heifers fed the late-cut hay averaged 60 lbs. less in weight than those fed the good hay. During the second year they still gained less rapidly, although both groups were fed some silage or green forage in addition to hay and concentrates.

If poor hay, low in carotene, must be used as the only roughage for calves and heifers, it is important to add a vitamin A supplement. Otherwise, a serious deficiency may result.[60]

In an area where but little legume hay is grown, alfalfa meal or alfalfa pellets make a satisfactory, though expensive, substitute for farm-raised hay. A suitable amount of the alfalfa meal or pellets may be mixed with the concentrates, and no other roughage fed.[61] When dehydrated alfalfa pellets are fed separately, calves may eat more pellets than they would of good alfalfa hay and will then gain correspondingly more.[62]

1135. Silage; roots.—After calves are 6 to 8 weeks old, they may be fed a small amount of good corn or sorghum silage, in addition to plenty of hay, but many dairymen prefer not to feed silage until the calves are 4 to 6 months old. The use of silage is not necessary in raising good calves, and feeding silage too early may cause more trouble from scours.

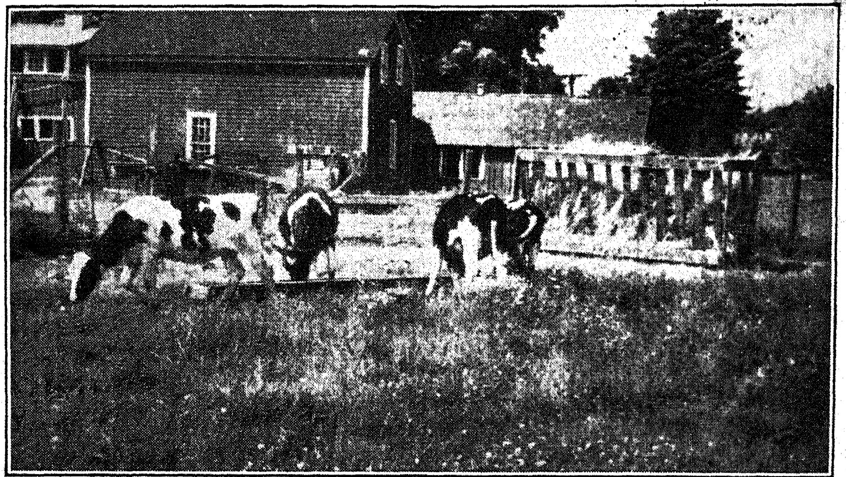
Corn or sorghum silage may be an economical addition to the rations of older calves and of heifers in the corn belt and in the sorghum-growing districts. However, such silage does not have the special nutritive values for calves which are possessed by good legume hay. This is because the silage is not rich in protein or in calcium, and it may have but little vitamin D. Hay-crop silage is a satisfactory substitute for part of the hay, especially for older calves and for heifers.

The results of experiments have differed widely in which hay-crop silage has been used as an entire substitute for hay in raising calves and heifers. In a trial by the United States Department of Agriculture, heifers were raised by the calf-starter method with a maximum of only 3 lbs. of concentrates a day and none after they were 8 months old.[58] Heifers fed wilted alfalfa silage as the only roughage or with a very small amount of hay did not eat anywhere near as much dry matter in roughage as others fed alfalfa hay, and did not make normal gains. After they were a year old, they made nearly as large gains as those fed alfalfa hay. It seemed that to produce equal gains with alfalfa silage it would be necessary to feed considerably more concentrates the first year than with alfalfa hay as the roughage.

Differing from these results, in New Hampshire trials yearling heifers made greater gains on hay-crop silage as the only feed than others made on hay, even

though they consumed less dry matter.[63] Also, in a Pennsylvania trial calves fed legume-grass silage as the only roughage made nearly as rapid gains as others fed hay, even when fed only a small amount of calf starter.[64] In Nevada and South Dakota tests heifers made only slightly less gain on alfalfa silage as the only roughage than others fed alfalfa hay, but in a Rhode Island trial hay-crop silage produced appreciably less gain than did corn silage.[65]

Where internal parasites are less serious, thrifty calves do well on clean pasture after they are 2 to 4 months old, if accustomed to it gradually and if they are fed plenty of other feed and are supplied with shade, shelter, salt, and fresh water. The scrawny, pot-bellied calves one often sees on pasture are usually not a result of the pasturage, but of the lack of milk and grain and of proper daily attention. In Georgia trials calves raised by the calf-starter method did well when



CALVES DO WELL ON PASTURE IF PROPERLY FED

Calves thrive on good pasture after they are 2 to 3 months old, if they are accustomed to it gradually and if they have plenty of other feed, as well as shelter, salt, and fresh water. A concentrate mixture is fed these heifers in a trough, and hay in a rack. (From New York State College of Agriculture, Cornell University.)

placed on fresh, clean pasture at only 7 days of age, with no hay at all.[67]

Roots are a satisfactory succulent feed for calves, but in the United States are much more expensive than silage.

1136. Pasture.—Pasture that is free from contamination with parasites is excellent for calves old enough to make good use of it. A pasture that has been grazed by cattle within a year or one that has been top-dressed with cattle manure should not be used for calves, as they are much more severely affected by internal parasites than are older cattle.

In the southern states the parasite problem is more serious than in the North, and North Carolina investigators advise that calves should not go to pasture until 10 months of age.[66] (1126)

If calves much under a year of age are pastured with older cattle, they may become badly infected with internal parasites from older cattle.

If calves are pastured when too young, there is more trouble from scours, and they may suffer from heat and flies. Many dairymen therefore prefer not to turn calves on pasture until they are 5 or 6 months old. Instead, the calves are kept in the stable, where they are more sure to receive proper feed and attention.

It has been pointed out previously in this chapter that direct sunlight is an effective aid in preventing or curing

rickets. During warm weather it is therefore well to let calves over 2 months of age have access to clean outside pens, if they are not on pasture.

1137. Raising calves on skimmilk.—Whenever skimmilk is available, the calves should be changed from whole milk to this by-product as soon as they have a good start. Calves raised on skimmilk may not make quite as rapid gains the first few months as when they are continued on a liberal allowance of whole milk. However, they will be just as large by the time they are 18 months to 2 years old and they will develop into just as productive cows.[68]

Skimmilk should be fed, if possible, fresh and warm from the farm separator. If the milk is not warm, it should be heated to 90° to 100° F. before feeding. Contrary to common opinion, it is not injurious to feed calves the foam which normally collects on separated milk, provided the proper amount of milk is fed. After the calf is 2 to 4 months old, it can usually be accustomed to cool milk, if the temperature is reasonably uniform. In a South Dakota trial, calves were successfully fed cold skimmilk from the start by means of nipple pails.[69] Sour skimmilk can be fed to calves 2 months old, if it is of good quality and if it is uniformly fed sour, and not sweet at one feeding and sour at another.

In raising calves on skimmilk, the change from whole milk to skimmilk may begin when the calf is 2 to 4 weeks old, the exact age depending on the vigor of the calf. The change should be made at the rate of about 1 lb. a day over a period of 7 to 10 days. In the case of very valuable calves, some whole milk is often fed for 2 months or longer. At the other extreme, in an experiment by the United States Department of Agriculture, calves were changed from colostrum to skimmilk on the fourth day of age with fair results.[70]

After the calf has been changed entirely to skimmilk, the allowance may be increased very gradually, if the calf is doing well. Not over 14 to 16 lbs. of skimmilk daily are needed, but if an excess is available after any pigs or poultry have been provided for, large vigorous calves may be fed somewhat more. Not more than 18 lbs. daily should be fed until the calf is 6 weeks old, but after this vigorous calves may have as much as they wish. If but a small amount of skimmilk is available, good gains can be secured on only 10 lbs. of skimmilk per calf daily, along with plenty of concentrates and good hay.[71]

If the supply is sufficient, skimmilk feeding should be continued for at least 6 months, but when the supply is scanty, thrifty calves can be weaned at 2 to 3 months and then be fed a calf starter.

For feeding with skimmilk any of the grain mixtures are satisfactory that have been previously suggested for feeding with milk. (1131) Experiments have shown clearly that for calves receiving a liberal amount of skimmilk, a concentrate mixture consisting chiefly or entirely of farm-grown grain is just as satisfactory as one containing a large proportion of protein-rich feeds.[72]

Sometimes fat or oil is mixed with skimmilk or reconstituted skimmilk, made from dried skimmilk, as a substitute for the fat in whole milk. However, the cereal grains, rich in carbohydrates, are cheaper and much more satisfactory. Ordinary plant oils, such as soybean oil or cottonseed oil, produce poor results, while calves do fairly well when lard or hydrogenated plant oil is added to the skimmilk.[73] The oil must be fed as an emulsion in the milk, or it is apt to cause indigestion and scours.

Minnesota and Missouri trials show that when an abundance of skimmilk is available, thrifty calves can be raised, after 2 to 3 weeks of whole milk feeding, on only skimmilk and alfalfa hay.[74] In the Minnesota test calves thus raised made normal gains and consumed 140 lbs. whole milk, 2,110 lbs. skimmilk, and 813 lbs. alfalfa hay to 6 months of age.

1138. Feeding buttermilk, whey, or reconstituted milk.—Fresh *buttermilk* that is sanitary and is not badly diluted is a good substitute for skimmilk in raising calves, and it may be used in the same manner. It is best not to begin changing calves from whole milk to but-

termilk until they are 4 weeks old, as buttermilk sometimes has a more laxative effect than skimmilk.

Whey can be used very successfully for calf feeding, when fed as recommended in Chapter XXIII. (889) If calves fed whey or reconstituted whey, made from dried whey, tend to scour, this can be prevented, according to Wyoming tests, by mixing one-quarter teaspoonful of slacked lime with each feeding.[75]

Sometimes *dried skimmilk* or *dried buttermilk* is mixed with warm water to make *reconstituted skimmilk* or *buttermilk*. This can be used satisfactorily in the same manner as ordinary skimmilk or buttermilk. (893) Dried skimmilk, dried buttermilk, and dried whey are also common ingredients in dry calf starters, or calf meals.

1139. Raising calves on nurse cows.—Where dairy by-products are not available on the farm, some use the "nurse-cow method" of raising calves with much success.[76] In this method 2 to 4 calves of about the same age and vigor are kept in a box stall with a cow, competing for her milk. The calves should be taught to eat a dry calf meal and hay as soon as possible and may be weaned, if necessary, at 2 to 3 months of age.

This system takes a minimum of labor and reduces the trouble from scours, if the number of calves is properly adjusted to the milk yield of the cow. During her lactation one cow may thus raise several calves to the weaning age. Often a hard milker or low tester can well be used for this purpose. New York tests indicate that a cow infected with mastitis can safely be used as a nurse cow, without infecting heifer calves that nurse her.[77]

1140. Raising calves on calf starters and a minimum of milk.—In market milk or condensary districts where no skimmilk, buttermilk, or whey is available, the calf starter method of raising calves is widely used. In this method the calves are given a good start on normal amounts of whole milk and are taught to eat a dry calf starter, or calf meal, and good hay as soon as possible. Then, if they are thrifty, the amount of milk is soon reduced and they are weaned entirely from fluid milk at 7 to 10 weeks of age. After this, they are fed only the calf starter, with plenty of first-class hay and with water to drink.

This method saves considerable labor in comparison with the feeding of reconstituted milk or of calf meal in gruel form, for there is no mixing and warming of a fluid food and washing and sterilizing of calf pails, after the calves are weaned. The results may be a little more variable with this method than when calves are raised on plenty of skimmilk. To secure the best results, the calves must be well started on the dry calf meal and hay before they are weaned from milk. Excellent-quality legume hay or mixed hay high in legumes must be fed, and if a calf is delicate or sickly, whole milk feeding must be continued until it is strong.

Some such schedule as the following should be followed under this plan: Feed a normal amount of whole milk during the first 3 weeks to Holstein, Brown Swiss, or Ayrshire calves and during the first 4 weeks to Jerseys and Guernseys. The maximum can be 10 lbs. a day for the former breeds and 7 lbs. for Jerseys and Guernseys. After this period, reduce the allowance for the larger breeds to 9 lbs. during the fourth week, 7 lbs. during the fifth week, 6 lbs. during the sixth week, and then gradually wean the calf during the next 7 to 10 days. In the case of a Jersey or Guernsey calf, reduce the milk allowance more gradually and do not wean the calf until 9 or 10 weeks of age, unless it is doing unusually well.

Until the calf is 3 months old, let it have all the dry calf meal it will eat, up to a maximum of 4 or possibly 5 lbs. a day, along with plenty of good hay. When the calf is about 3 months old, supply a simple "growing mixture," in addition to the more expensive calf starter. Any of the mixtures previously suggested for milk-fed calves will be satisfactory, which contain linseed meal, wheat bran, or other protein supplements. (1131) When the calf is 4 months

old, the calf starter can be discontinued and the cheaper mixture fed, along with the hay.

In this method not over about 350 lbs. of whole milk need be fed, in addition to the colostrum during the first 3 days, which is not marketable. To reduce the amount of whole milk used, the feeding of milk in this method is sometimes discontinued at an earlier age than stated. However, the calves then often gain poorly for a month or more, and become pot-bellied and scrawny. Later, they may make good gains and reach normal weight and height at 12 to 24 months of age.

Numerous experiments have shown that very satisfactory results are generally secured when calves are raised by the calf starter method, if a total of about 350 lbs. of whole milk, in addition to colostrum, is fed and plenty of good quality hay is supplied. For example, this method has been used very successfully at the New York (Cornell) Station during the past 20 years in extensive experiments in which various calf starters have been compared.[78] In these experiments, calves of the various dairy breeds have made satisfactory growth with this system. The gains to 4 months of age have usually been slightly greater than the normal rate in dairy herds. Similar results have been secured in numerous experiments elsewhere with dry calf starters or calf meals.[79]

When calves are raised by the calf-starter method, good results are secured with more uniformity if the feeding of whole milk is continued until the calves are 7 to 10 weeks old. However, if an effective antibiotic feed supplement is added to the milk, the results are usually satisfactory when milk feeding is discontinued at 5 weeks, and a total of only about 175 lbs. of milk is fed. If a calf is not growing thriftily, milk feeding should be continued longer.

1141. Formulas for calf starters.—Many different formulas for calf starters have been used successfully in the experiments with this method of raising calves. It was concluded in the New York experiments, for example, that no one calf starter proved to be consistently better than all others.

The calf starters commonly used have about 20 per cent protein and thus must include a rather large proportion of protein-rich supplements. A calf starter should be very rich in total digestible nutrients, and should therefore not have more than about 5 per cent of fiber. In a recent Kentucky experiment a calf starter containing only 16.6 per cent protein, fed with excellent alfalfa-bromegrass hay, gave about as good results as starters higher in protein.[80]

Most of the calf starters used earlier contained 20 per cent or more of dried skimmilk or equivalent amounts of fish meal, meat scrap, or tankage. Later experiments have shown that protein supplements of animal origin are not necessary in a calf starter, if a considerable part of the protein comes from properly cooked soybean oil meal and if the calves are fed about 350 lbs. of milk (not including colostrum).[81]

When less whole milk is fed and the calves are weaned before the age of 7 to 9 weeks, there should preferably be at least 5 per cent of dried skimmilk or other suitable feed of animal origin in the calf starter. Satisfactory results were secured in the New York trials with calf starters containing only 5 per cent of dried whey as the feed of animal origin. These starters also contained 14 per cent of soybean oil meal and 10 per cent of linseed meal, or else 20 per cent of linseed meal, along with 5 per cent of alfalfa meal and with mineral supplements and irradiated yeast in addition.

A calf starter is more palatable when the grain is ground coarse instead of fine.[82] Pelleting a calf starter or part of the ingredients did not increase the palatability or the value in Kansas, Kentucky, Maryland and New York tests.[83]

Yellow corn is an excellent grain to include in a calf starter, because of its vitamin A value. Ground or crushed oats is a popular ingredient, and is as satisfactory as the more expensive rolled oats, without the hulls. Other ground grain, such as grain sorghum, can be used in addition to corn and oats or as a

substitute for them. The addition of 5 to 8 per cent of cane molasses seems to improve the palatability of a calf starter slightly.

In a calf starter in which soybean oil meal provides much of the protein, 10 to 20 per cent of distillers dried solubles is a satisfactory substitute for dried skimmilk or dried whey and dried yeast. (955) Cottonseed meal, even that which is degossypolized, is less satisfactory than soybean oil meal as the chief protein supplement.[84]

To help insure a plentiful supply of vitamins and minerals, it is well to have in a calf starter 5 to 7 per cent of high-grade alfalfa meal or alfalfa leaf meal, 0.5 per cent of ground limestone, 0.5 per cent of bone meal or other safe phosphorus supplement, 0.5 per cent salt, and 0.025 to 0.05 per cent of irradiated yeast or 0.125 per cent of cod-liver oil concentrate.

The following are examples of calf-starter formulas which have proven very satisfactory:

(1) Cracked yellow corn, 19.475 lbs.; crushed oats, 20.0 lbs.; wheat bran, 15.0 lbs.; linseed meal, 10.0 lbs.; dried skimmilk, 5.0 lbs.; soybean oil meal, 14.0 lbs.; cane molasses, 5.0 lbs.; alfalfa meal, 7.0 lbs.; brewers' yeast, 3.0 lbs.; irradiated yeast, 0.025 lb.; ground limestone, 0.50 lb.; steamed bone meal or dicalcium phosphate, 0.50 lb.; iodized salt, 0.50 lb. (Dried whey can be used in place of the dried skimmilk, and the linseed meal or soybean oil meal increased slightly.)

(2) Yellow corn meal, 24.775 lbs.; crushed oats, 20.0 lbs.; wheat bran, 15.0 lbs.; linseed meal, 10.0 lbs.; soybean oil meal, 18.2 lbs.; cane molasses, 5.0 lbs.; alfalfa meal, 5.0 lbs.; irradiated yeast, 0.025 lb.; ground limestone, 0.50 lb.; bone meal or dicalcium phosphate, 1.00 lb.; salt, 0.50 lb.

(3a) For feeding with plenty of good alfalfa or other legume hay: Ground grain sorghum, 300 lbs.; cottonseed meal or soybean oil meal, 200 lbs.; wheat bran, 100 lbs.; steamed bone meal, 3 lbs.; salt, 3 lbs.

(3b) For feeding with poorer hay: Ground grain sorghum, 300 lbs.; cottonseed meal or soybean oil meal, 150 lbs.; wheat bran, 100 lbs.; alfalfa leaf meal, 50 lbs.; brewers' dried yeast, 25 lbs.; steamed bone meal, 3 lbs.; salt, 3 lbs.

When a total of about 400 lbs. of whole milk (not including colostrum) is fed per calf and care is taken to supply first-class hay, a very simple calf starter can be used. In Wisconsin experiments Guernsey and Holstein calves thus fed made normal gains on a calf starter containing only equal parts by weight of ground yellow corn, ground oats, wheat bran, and linseed meal.[85] Though these calves did not gain as rapidly as others fed skimmilk to 6 months of age, they would later make up all or most of this difference, if they were well fed up to calving time.

1142. Milk replacers or substitutes.—Many experiments have been conducted recently to devise milk replacers or substitutes for raising calves with no whole milk after only a few days of age.[86] Such milk replacers are usually fed in the form of a warm gruel, and in addition the calves are supplied a less expensive dry calf starter and good hay.

When the feeding of whole milk is discontinued at 10 days of age or less and a good milk replacer fed in gruel form instead, calves can usually be raised successfully. However, they often are less thrifty and grow less rapidly than those raised by the calf-starter method with a total of about 350 lbs. of whole milk. If well fed later, they tend to develop normally.

Several milk replacers are now made by feed manufacturers, and these should be used according to the directions which are supplied. The most efficient milk replacers generally contain a large percentage of dried skimmilk, dried whey or other dairy by-products, along with other feeds, vitamin supplements, minerals, and perhaps an antibiotic. For example, a satisfactory milk replacer used in New York experiments contained: 50 lbs. dried skimmilk, 30 lbs. dried whey, 7.76 lbs. dextrose, 5 lbs. oat flour, 4.9 lbs. brewers' dried yeast, 0.1 lb. irradiated yeast, 2.2 lbs. stabilized vitamin A sup-

plement, and 0.04 lb. trace mineral supplement.[87]

As Allen of the Wisconsin Station points out, the use of a milk replacer certainly does not provide better nutrition or reduce losses, in comparison with the calf-starter method and more whole milk. Also, the feeding of a milk replacer as a warm gruel requires more time and bother.[88] It takes at least 20 lbs. of a milk replacer to furnish as much nutrients and energy as in 100 lbs. of whole milk. He concludes that one cannot save enough money to pay for the extra trouble in using a milk replacer unless he can buy a 25 lb. sack of milk replacer for the net farm price received for 100 lbs. of milk.

1143. Self-feeding calves.—Since the self-feeder is used so successfully for pigs, experiments have been conducted to find whether or not calves can be raised satisfactorily by self-feeding them concentrates in addition to supplying milk and roughage.[89] These trials have shown that if calves or heifers are self-fed, free choice, such grains as corn and oats, and also linseed meal, wheat bran, and other protein supplements, they will usually eat much more of the protein supplements than they need. This will make the cost unduly high.

Also, even if the calves are self-fed a mixture containing the proper proportion of protein supplements, after 2 to 4 months they will often eat much more concentrates than they need and less hay than they should take. This is expensive, but even more important, the amount of hay may be so small that the calves may become unthrifty, due to a lack of the vitamins and minerals good hay provides. They may suffer from rickets and even have fits and convulsions.

By using a mixture of the proper proportions of chopped or ground legume hay and concentrates in a self-feeder this difficulty can be avoided, but the proportion of hay must be carefully adjusted, so that the calves will eat plenty of hay and yet make the desired gain.

III. Dairy Heifers

1144. Grow heifers well.—Rearing heifers after they are 6 months old is an easy task. Perhaps for this very reason, many are stunted for lack of proper feed and attention and fail to develop into profitable cows. Also, if a dairyman raises surplus cattle for sale, he soon finds that buyers do not want undersized heifers or cows, but they look for well-grown animals which give indications of large and profitable production. The proper development of the heifers is therefore an exceedingly important part of the dairy business.

As is shown in the following articles, it is entirely unnecessary to feed heifers expensively to secure good growth and development. All that is necessary is plenty of first-class roughage in winter and good pasture the rest of the year with only a minimum amount of a suitable concentrate mixture when needed.

1145. Nutrient requirements.—The nutrient requirements for growing dairy cattle have been discussed in detail earlier in this chapter. In considering the feeding of heifers after 6 months of age, the following special points about their nutrient requirements should be borne in mind.

Far too often, heifers are fed only fair or poor roughage in winter and are turned on pasture and allowed to shift for themselves in summer, with but little attention, even when the feed becomes scanty. Such neglect is perhaps due to the fact that the heifers are not bringing in any immediate cash income, and a lack of sufficient appreciation that the future income will depend on how the heifers are developed.

Heifers cannot make normal growth unless they receive an adequate supply of total digestible nutrients. Since hay and other roughages are bulky and relatively low in digestible nutrients, young heifers fed roughage alone, without grain or other concentrates, cannot consume enough of the bulky feed to provide sufficient nutrients for good growth. After they are a year old, their digestive tracts are well developed, so they can be wintered satisfactorily on roughage with little or no concentrates, if the roughage is of satisfactory quality.

Raising heifers on an abundance of

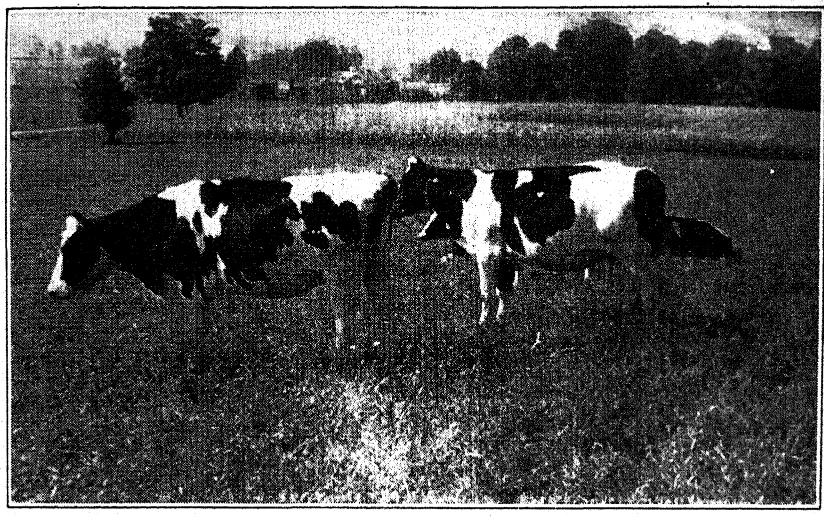
good hay and other roughage, with just enough concentrates to keep them growing properly, is nearly always much more economical than feeding them a large allowance of concentrates with less roughage. Heifers fed liberally on concentrates will make rapid growth and be sleek and fat, but such wasteful feeding is actually detrimental to their future usefulness.

It has been pointed out earlier in this chapter that there is more apt to be a deficiency of phosphorus than of calcium in raising heifers. Whenever there may be a lack of these or other minerals, a suitable mineral supplement should be supplied.

If heifers are fed early-cut, well-cured hay in winter, especially legume or mixed hay, and are on good pasture in summer, they will receive an abundance of vitamins.

1146. Levels of feeding.—Several long-time experiments are being conducted in this and other countries to determine the effects of different levels of concentrate feeding of heifers up to the first calving, upon milk production in successive lactations and length of productive life.[90] The results thus far secured show clearly that overfeeding heifers on concentrates, so that they become very fat before freshening, not only is exceedingly uneconomical but also is apt to be definitely injurious.

It is more difficult to get heifers that are thus fed in calf, and their milk production when they freshen is often very disappointing. Such overfeeding tends to produce a heavy, coarse build and to cause undue fat deposition in the udder. This may never disappear after the heifer freshens. The udder is apt to be fleshy and meaty, instead of being composed almost entirely of milk-secreting tissue.



WELL-GROWN HEIFERS ON FINE PASTURE

To reduce the cost of raising heifers and at the same time secure good growth and development, the heifers must have plenty of first-class pasture in summer and all the good roughage they will eat in winter. (From New York State College of Agriculture, Cornell University.)

Heifers that are fed up to calving on rations which supply a scanty amount of total digestible nutrients and net energy, but plenty of minerals and vitamins, do not grow at a normal rate and do not come into heat as early as those fed adequate rations. If such heifers are fed a much more liberal amount of concentrates than usual during their first lactations, they will be able to grow enough

to make up much of the difference in size. They may even produce nearly as much milk as normal in the first lactation, and if well fed in later lactations will continue to grow and may reach almost normal size.

The results are much different from this on most farms where heifers are badly underfed up to the time they freshen. Usually the heifers, which are small and poorly developed, are not fed with great liberality during their first lactation. Consequently, they become stunted, undersized cows, and their milk production is much less than it would have been if they had been developed properly.

In certain of the long-time experiments heifers which were grown more slowly than normal tended to live longer, because they matured more slowly. However, these experiments do not show that it would be economical to follow such a method in raising heifers, instead of developing them well up to the time of calving.

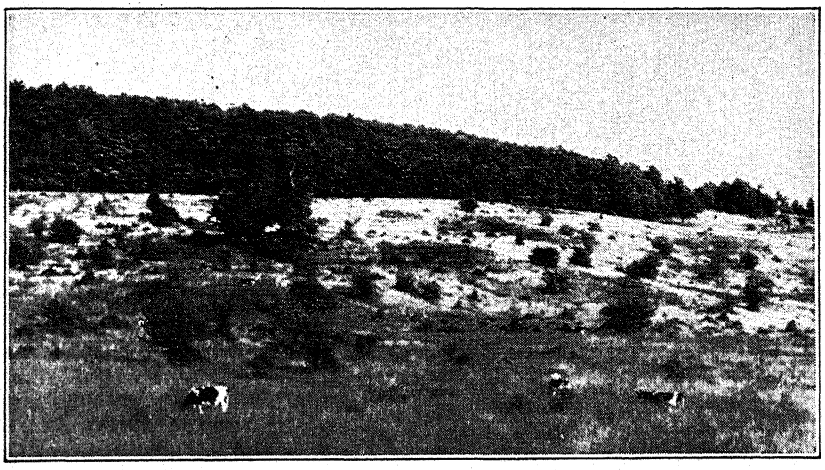
1147. Roughages for heifers.—In winter there is no better ration for heifers than legume hay or mixed hay high in legumes, with or without silage, and with a sufficient amount of a suitable grain mixture to keep them growing thriftily.

If possible, at least half of the winter roughage on the dry basis should be well-cured legume or mixed hay, for it supplies needed protein, calcium, carotene and vitamin D. If legume hay is not available, early-cut and well-cured grass hay should be used. Even such grass hay should be fed, if possible, along with some legume hay or with silage.

When there is little or no legume roughage in the winter ration, care must be taken to feed a sufficient amount of protein supplement to balance it properly. Also, a calcium supplement may be needed. **(1116)**

The importance of good hay for heifers is shown by New York tests.[91] Heifers fed poor-grade alfalfa hay with 6 lbs. of concentrates per head daily did not gain as rapidly as others fed only 3 lbs. of concentrates a day with U.S. No. 1 alfalfa hay. In another experiment young heifers would eat only 0.9 lb. a day of ripe bluegrass hay, while they consumed 4.1 lbs. of No. 1 mixed legume-grass hay.

If necessary, a limited amount of poorer roughage can be fed, along with



HEIFERS ARE OFTEN NEGLECTED ON POOR PASTURES

Often heifers are turned in summer on poor, unimproved pasture, such as this, and allowed to shift for themselves, with little attention. (From New York State College of Agriculture, Cornell University.)

good legume hay or with silage. Cut or shredded fodder or stover from corn or sorghums, cottonseed hulls, or even straw from the grains can be thus used. To get heifers to eat enough unpalatable roughage, diluted molasses may be poured over it. Thus fed on cut corn stover in a Wisconsin test, molasses was worth fully as much as ground corn per pound.[92]

Silage is excellent for heifers when fed as part of the roughage, along with legume or mixed hay. However, silage is not at all necessary if an abundance of good hay is fed. For heifers, just as with dairy cows, it requires about 3 tons of corn silage to equal 1 ton of legume or mixed hay in value.[93]

Heifers may be wintered satisfactorily on corn or sorghum silage as the only roughage, if a concentrate mixture is fed which furnishes plenty of protein,[94] but often they show a great desire for some dry forage. It is therefore wise to feed some hay or even dry fodder or stover from corn or the sorghums along with the silage.

1148. Concentrates for heifers.—All the grains may be used satisfactorily, when ground or crushed, for feeding heifers, and their relative values for this purpose will be about the same as for dairy cows. Other low-protein concentrates, such as hominy feed, dried beet pulp, dried citrus pulp, or molasses, can be substituted for grain. The use and relative values of these feeds have been discussed in the chapters of Part II.

Linseed meal, soybean oil meal, cottonseed meal, and wheat bran are the most commonly used protein supplements for heifers, but the other protein supplements that are satisfactory for dairy cows are likewise suitable for heifers. As has been shown in Chapter XXII, heifers over 3 to 4 months of age may even be fed cottonseed meal as the only concentrate without injury, if roughage is fed which supplies plenty of vitamins and if there is ample calcium in the ration. **(811)**

The use of urea as a substitute for part of the protein in rations for dairy cattle has been discussed in Chapter XXV. **(1019)**

1149. Feedng heifers from 6 to 12 months of age.—The feeding of milk or special calf meals is usually discontinued by the time heifers are 6 months of age, or even before. They should have an abundance of other feeds at this time, so that their growth will not be checked.

Numerous experiments have been conducted to find if heifers can be wintered satisfactorily on roughage alone.[95] These experiments show that when heifers are fed only roughage, even of good quality, before they are 10 to 12 months of age, they will not make normal growth. They will make up their growth to some extent later if well-fed, and may even reach normal size if fed liberally after they freshen. However, unless grain is unusually high in price in comparison with roughage, it is generally advisable to feed heifers under a year of age sufficient concentrates, in addition to an abundance of good roughage, so that they will make normal growth.

Experiments mentioned previously show that if heifers are fed an abundance of excellent legume hay, they may make normal growth when fed no concentrates after 8 months of age. **(1134)**

The amount of concentrates needed by heifers 6 to 12 months of age will, of course, depend on the quality and amount of roughage. With plenty of good roughage, 2 to 4 lbs. of concentrates per head daily should be enough, while with that of only fair quality 4 to 6 lbs. may be needed to keep the heifers gaining properly. Heifers 6 to 12 months of age should be fed 8 to 15 lbs. of hay a day, or 5 to 10 lbs. of hay and 8 to 15 lbs. of silage.

Whether it will be necessary to feed grain or other concentrates to heifers of this age on pasture will depend on how good the pasture is. If it supplies plenty of high-quality forage, they will make satisfactory growth on pasture alone.[96] However, on average pasture it is often necessary to feed a small amount of concentrates to keep them growing well. Whenever the pasture becomes scanty, it is especially important to provide plenty of other feed, including concentrates and also hay, silage, or green soiling crops. In

the spring when young heifers are first turned to pasture, it is best to continue feeding some hay until they get used to the lush, laxative green feed.

If the heifers are fed plenty of alfalfa, clover, or other legume hay as the only roughage, or if they are on good pasture which is kept well grazed, no protein supplements need be included in the concentrate mixture. Merely ground grain alone, even corn, is satisfactory. The mixture may be any desired combination of the common cereals.

Appendix Table VII gives a considerable number of concentrate mixtures containing various percentages of protein, which are excellent for dairy heifers. As shown in this table, concentrate mixtures containing 12 to 14 per cent total protein are recommended when only about half the dry matter of the roughage comes from legumes. With little or no legume roughage, the concentrate mixture should have 16 to 18 per cent protein.

1150. Feeding heifers over one year of age.—After heifers are a year of age they may be wintered satisfactorily, up to 3 or 4 months before calving, without concentrates, if fed either an abundance of good legume or mixed hay and silage, or else all the well-cured legume hay they will eat.[97] They will not carry as much flesh as some breeders desire, but if well fed before calving and during their first lactation period, they will reach normal size and weight.

With roughage of ordinary quality, it is necessary to feed a small amount of concentrates to keep heifers growing properly. If the roughage is fair in quality, not over 2 to 4 lbs. of concentrates should be needed up to 3 or 4 months before calving. At this time they should be fed more liberally, so as to supply nutrients for the development of the fetus and also so the heifers will be in good condition for high production during their first lactation. With plenty of good roughage, 4 to 5 lbs. of concentrates are sufficient at this time.

Yearling heifers do well on good pasture without any concentrates, if they can actually secure plenty of forage.[98] If the pasturage gets scanty, it should be supplemented with enough other feed—concentrates, hay, or silage—to keep them growing satisfactorily.

The same concentrate mixtures may be used for heifers of this age as for those up to a year of age. If desired, the proportion of protein supplement in the mixture may be reduced slightly, as heifers need somewhat less protein as they become older.

1151. Age for first calving.—Heifers that are well-grown for their age may be bred to calve at an earlier age than those which are undersized. Well-grown Holsteins may be bred to calve at 24 to 28 months; Brown Swiss a little later; Ayrshires and Guernseys, 23 to 27 months, and Jerseys, 22 to 27 months.[99]

Wisconsin studies indicate that, if heifers are properly developed, their total production up to a given age will be greater if they first freshen when slightly younger than is the practice in many dairy herds.[100] Holstein heifers in dairy-herd-improvement association herds that calved at 22 to 25 months of age produced on the average a total of 1,920 lbs. of butterfat to 7 years of age. Those that calved first at 28 to 29 months of age produced only 1,760 lbs., and those not calving until 30 to 31 months only 1,720 lbs.

Heifers that calve relatively early will not produce quite as much milk in their first lactation as when calving is delayed a few months. However, considering the additional cost of carrying a non-producing heifer a longer time, fairly early calving is generally more profitable. Also, if breeding is delayed too long, it is often much more difficult to get a heifer in calf.

Heifers that calve early must be fed liberally during their first lactation period, so that their growth will not be stopped. Otherwise, they will not reach normal mature size.

1152. Normal growth of dairy cattle.—In order to determine whether young dairy cattle are making the proper rate of growth for the particular breed, it is helpful to have a normal standard with which they can be compared. At

several experiment stations the weight and also the height at the withers have therefore been recorded each month during growth for young heifers and bulls of the chief dairy breeds.

The following table summarizes available data of this kind for young cattle up to 2 years of age. Records are included from the Iowa, Kansas, Missouri, Nebraska, South Carolina, and West Virginia Stations, and from the United States Department of Agriculture.[101] For each breed the averages represent data for a much larger number of animals at early ages than later ages. The average heights shown in the table are for smaller numbers of animals, and the number of bulls included in the studies was much less than of heifers. For the younger ages the average weights are for the following maximum numbers of heifers: Ayrshires, 390; Guernseys, 88; Holsteins, 885; and Jerseys, 507.

Normal growth in weight and height of dairy cattle

Age	Ayrshire heifers		Guernsey heifers		Holstein heifers		Jersey heifers	
	Weight	Height	Weight	Height	Weight	Height	Weight	Height
Months	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches
Birth ...	71	...	65	26.6	93	28.9	50	25.8
1	86	27.0	79	28.4	115	30.5	70	26.9
2	114	28.4	105	30.0	155	32.2	96	28.8
4	190	32.0	177	33.7	260	36.2	176	32.7
6	281	35.3	267	37.2	379	39.8	268	36.2
8	371	37.7	350	39.9	491	42.4	357	39.1
10	451	39.6	427	41.7	589	44.6	432	41.0
12	518	42.6	490	43.3	685	46.2	495	42.3
14	576	43.8	556	44.6	752	47.6	549	43.5
16	635	44.8	605	45.3	820	48.8	597	44.5
18	690	45.7	663	46.4	890	49.7	644	45.3
20	743	46.5	712	47.0	961	50.6	694	46.0
22	790	47.3	763	47.7	1038	51.3	742	46.6
24	845	47.7	818	48.0	1104	51.9	785	47.0

Age	Ayrshire bulls		Guernsey bulls		Holstein bulls		Jersey bulls	
	Weight	Height	Weight	Height	Weight	Height	Weight	Height
Months	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches
Birth ...	78	27.9	71	27.7	99	29.4	61	26.2
1	94	28.3	87	29.3	124	30.9	81	27.9
2	125	30.0	113	30.6	166	32.8	115	29.7
4	214	33.9	190	34.2	286	36.4	209	33.6
6	324	37.6	291	37.8	428	40.6	319	37.2
8	437	40.4	401	40.3	565	43.4	429	39.5
10	536	42.3	494	42.5	687	45.6	526	41.4
12	621	43.8	609	44.5	808	47.8	626	43.0
14	670	44.7			922	49.3	709	45.0
16	724	45.6			1063	51.0	780	46.1
18	751	46.4			1216	52.8	864	47.5
20	819	47.0			1320	53.7		48.6
22	895	47.6			1376	55.3		49.3
24	990	48.1			1452	56.0		50.3

At one year of age the Ayrshire heifers averaged 518 lbs. in weight; the Guernseys, 490 lbs.; the Holsteins, 685 lbs.; and the Jerseys, 495 lbs. The gains during the first year averaged 1.62 lbs. per head daily for the Holsteins; 1.22 lbs. for the Ayrshires; 1.16 lbs. for the

Guernseys; and 1.20 lbs. for the Jerseys.

The gains during the second year were somewhat less rapid, averaging 1.15 lbs. per head daily for the Holstein heifers; 0.90 lb. for the Guernseys and Ayrshires; and 0.79 lb. for the Jerseys. After 2 years of age, increase in weight continues at a much reduced rate until dairy cattle reach mature weights at 6 or 7 years. Maximum height is reached somewhat earlier.

The bulls made distinctly more rapid gains than the heifers of the same breed and also were usually taller at a given age.

1153. Cost of raising heifers.—The cost of raising dairy heifers up to the time of first calving differs rather widely in various sections, depending chiefly on the prices of feeds. Feed and bedding usually make up about two-thirds of the total cost. To this expense must be added the initial value of the calf and the expenses for labor, shelter, interest, taxes, and miscellaneous items. From the gross cost should be deducted a credit for the manure produced.

The feed cost of raising heifers can be greatly reduced by providing plenty of excellent hay or hay and silage, as this decreases the amount of concentrates needed for growth. For example, in a recent United States Department of Agriculture experiment Holstein and Jersey heifers fed an abundance of excellent alfalfa hay or alfalfa hay and silage made normal gains to 2 years of age with a total of about 560 lbs. of concentrates and no milk after they were 60 days old.[58]

Except in sections where feed is cheap, the cost of raising heifers is often greater than the selling price of grade dairy heifers of ordinary quality. Care should therefore be taken to raise only heifers that are out of high-producing cows and that are sired by a good pure-bred bull. If more of such heifers are raised than are needed for replacements, they are the kind that will bring good prices. Heifer calves that are out of poor cows or those that are otherwise undesirable should not be raised, for they will not be worth the expense involved.

An interesting method of estimating whether a heifer calf will be a good milk producer has been developed by Swett and associates of the United States Department of Agriculture.[102] They have found that the size of the actual udder tissue in calves 3 to 6 months old is a fair indication of their future milk production, and have prepared a detailed grading system for selecting heifers for herd replacements on this basis.

Since feed is by far the largest item in the cost of raising heifers, the cost with various feed prices can be estimated from the data in the following table. This shows the amounts of feed needed to raise dairy heifers either to 2 years of age or to the time of first calving, as found in various studies.[103]

Amount of feed required to raise dairy heifers

	Whole milk	Skim-milk	Concen-trates	Hay and dry roughage	Silage, etc.	Pasture
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Days
New York, various breeds	814 *	....	945	3,600	3,200	†
Maryland, various breeds	368 ‡	....	1,752	3,492	2,208	312
Ohio, Holsteins	499	2,960	1,526	2,448	2,833	281
Ohio, Jerseys	465	3,015	1,382	2,041	2,884	281
Louisiana, Holsteins	827	2,775	896	2,589	1,934	†
Oregon, various breeds	552	1,209	230	3,260	1,180	358
Missouri, Holsteins	293	1,907	1,416	3,719	1,436	317

* Includes both whole milk and some skimmilk.
† Number of days of pasture not stated.
‡ In addition, nurse cows were used for some of the calves.

The New York and Maryland data represent the methods used in raising calves in the market-milk districts of

the eastern states. In the other studies considerable amounts of skimmilk were fed. The amounts of concentrates were low for the Louisiana and Oregon heifers, chiefly because pasture could be provided over a longer season than is possible in the central and northeastern states.

IV. The Bull

1154. Bred-for-production sires essential.—A dairyman cannot expect to improve the productive capacity and profitableness of his herd unless the heifers he raises are sired by a bred-for-production bull. The sire should be selected primarily on the basis of actual records of production of his immediate ancestors and their offspring, and not chiefly because of their show-ring winnings. Due attention must also be given to the conformation and type of the bull and his ancestors. If a poor bull is used, it will take years of constructive breeding to undo the damage.

As the average production of the cows in a herd increases, it becomes more and more difficult to select a bull whose daughters will be better than their dams, or that will even maintain a high level of production in the herd. In such herds it is especially desirable to use a "proved sire," whose ability to transmit high production has been definitely proved by the actual records of his daughters in comparison with the records of their dams.

Relatively few proved sires of superior merit are available, and therefore the average dairyman cannot himself own such a bull. Fortunately, the recent rapid development of artificial breeding associations in this country has revolutionized dairy cattle breeding. In most of our dairy districts, even a dairyman with a small herd can now, at moderate expense, have his cows inseminated with semen from bulls of outstanding transmitting ability.

1155. The young bull.—The same principles apply in the rearing of the young bull as with heifers, and the same methods of feeding can be used, except that it is wise not to limit the amount of milk so much as to check his growth. A young bull should always be fed so as to make good growth and reach normal size. One which has been stunted by insufficient feed may sire just as large calves, but a purchaser does not desire such an animal. He never knows whether the small size is due to heredity or to scanty feed.

Sexual maturity was delayed 4 to 14 weeks in New York and Pennsylvania experiments when bull calves were raised on rations that supplied only 60 to 75 per cent as much total digestible nutrients as advised in the feeding standards for growing dairy cattle.[104] Also, on the scanty rations the amount and quality of semen produced was lowered.

So far as is known, the protein, mineral and vitamin requirements of a young bull are the same as for a heifer. One should guard against any deficiency of vitamins or minerals, which might injure the health of the bull or lower his future breeding efficiency. However, there is no advantage in using special vitamin or mineral supplements, unless there is an actual deficiency in the ration.

In experiments by the United States Department of Agriculture bulls were raised on rations low in carotene, in which the only roughage was poor-quality timothy hay.[105] To these rations were added various amounts of vitamin A supplements to determine the requirements. It was found that decided physical symptoms of vitamin A deficiency usually appeared before the reproductive performance of a bull was lowered. Some of the bulls even continued to breed after they had become blind because of vitamin A deficiency.

After 5 to 6 months of age, when a bull calf should be separated from the heifers, he should have a somewhat larger amount of concentrates than a heifer. This is because a young bull makes more rapid gains than a heifer and consequently needs more nutrients. If well grown, a bull should be sufficiently mature for very light service at 10 to 12 months of age, but not more than 1 or 2 services in any one week should be permitted until he is 2 years old.

The bull should be halter broken as a calf, and at about 1 year of age should have a stout ring inserted in his nose. When he is about 2 years old this should be replaced by a larger one, and the ring must never be allowed to wear thin. He should be so handled from calfhood that he will recognize man as his master, and he should never be given an opportunity to learn his great strength. Stall and fences should always be so strongly built that there is no possibility of his learning how to break loose.

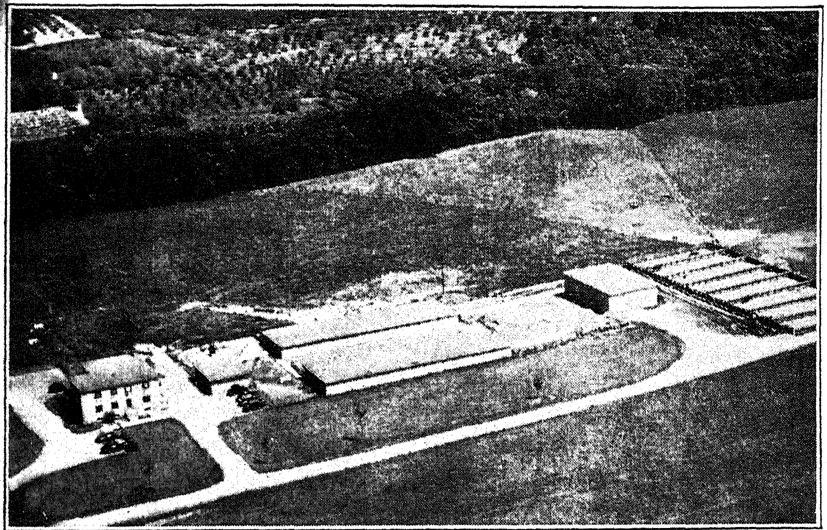
1156. Feeding the bull in service.—The bull in service should be fed good roughage and sufficient concentrates to keep him in thrifty condition, but not fat.

It was found in a New York experiment that to maintain the weights of bulls in heavy service satisfactorily, 8 to 11 per cent more total digestible nutrients were required than the higher set of recommendations made in the Morrison standards for the maintenance of dairy cows.[106] Based upon these experiments, feeding standard recommendations for total digestible nutrients were proposed, which are followed in the feeding standards given in Appendix Table III of this volume.

In these New York trials, the bulls needed about 0.4 to 0.5 lb. of concentrate mixture daily per 100 lbs. live weight, along with 0.9 to 1.0 lb. of hay per 100 lbs. weight. When fed only as much total digestible nutrients as required to maintain dry dairy cows, the bulls lost weight, but the volume or quality of the semen was not lowered in 90-day periods.

Good legume hay or mixed legume-grass hay is unexcelled as roughage for bulls. When hay is the only roughage, 15 to 20 lbs. a day is usually fed, depending on the size of the bull.

Opinions differ concerning the feeding of silage to bulls in service. Some advise feeding no more than 10 to 15 lbs. of silage a day, and believe that a



NEW YORK DAIRY CATTLE BREEDING CENTER

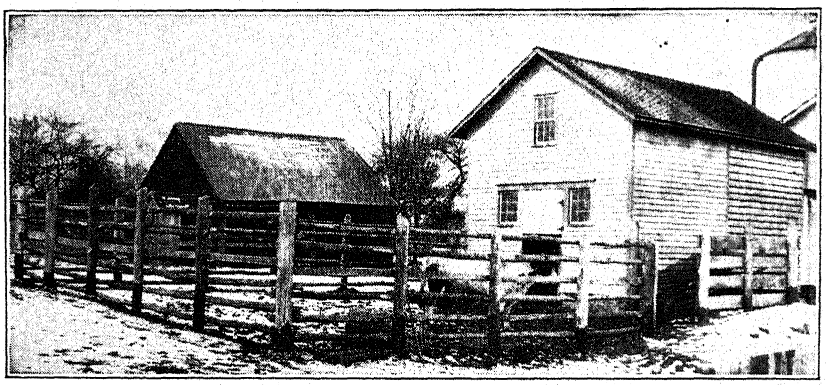
Airplane view of the Dairy Cattle Breeding Center at Cornell University, conducted cooperatively by the New York Artificial Breeders Cooperative, Incorporated, and the Animal Husbandry Department of the University. Laboratory and office building at left, one-story bull barns in center, and paddocks at extreme right. Semen produced here is distributed state-wide to local Artificial Breeding Associations, which breed over one-fourth of all the dairy cows in the state.

large amount tends to make a bull paunchy, so that he will be clumsy and slow at service. However, in recent Pennsylvania and Wisconsin trials bulls have been fed as much as 4 lbs. of hay-crop silage per 100 lbs. live weight with no impairment of breeding ability or quality of semen.[107] In the Wisconsin test bulls were maintained in satisfactory breeding condition on 45 lbs. of silage and 25 lbs. of alfalfa-bromegrass hay per head daily, without any concentrates.

Pasture is excellent for bulls, and if a safely fenced pasture paddock can be provided, the cost of feed during the growing season can be thus reduced. However, experiments have shown that the semen production is as good from bulls fed good hay, without pasture, as when pasture is furnished.[108]

A bull does not need nearly so much protein in his ration as a high-producing cow in milk, and should be fed the same sort of concentrate mixture as is used for dry cows or growing heifers. In a New York experiment it was found that a concentrate mixture having only 12 per cent of total protein was just as satisfactory as one higher in protein, when fed with good-quality mixed grass-and-legume hay having only 10 per cent legumes but containing 8.9 per cent protein. Similar results were secured in a New Jersey experiment.[74]

Differing from the opinions of certain Russian investigators,[109] it seems safe to conclude that when bulls are fed reasonably good roughage, the quality of protein in the concentrate mixture is not important. In a New York experiment with 18 bulls used in artificial insemination, bulls fed timothy hay as the only roughage produced about as much and as good semen with corn gluten feed as the only protein supplement, as when better-quality protein was provided by dried skimmilk or soybean oil meal.[110]



SAFETY BULL PEN WITH BREEDING CHUTE AND BREEDING RACK

This bull pen is equipped with a breeding chute and a breeding rack at the right, next to the shed, so that it is not necessary to handle the bull at time of service. The bull can exercise at will in the strongly-fenced pen. Note the steel oil drum in the pen near the corner. The bull plays with this and bunts it about, thus getting more exercise. (From Goodman, New York State College of Agriculture, Cornell University.)

There is no need to feed a complex concentrate mixture to bulls, or to add vitamin supplements or a complex mineral mixture to ordinary good rations. In a New Jersey experiment one group of bulls was fed a very simple concentrate mixture with mixed timothy-and-clover hay of average quality from the age of 18 months until they were about 3 years old.[111] Another similar group was fed a very complex concentrate mixture with the same kind of roughage.

The simple mixture consisted of ground yellow corn, corn gluten meal, dried beet pulp, and cane molasses, with

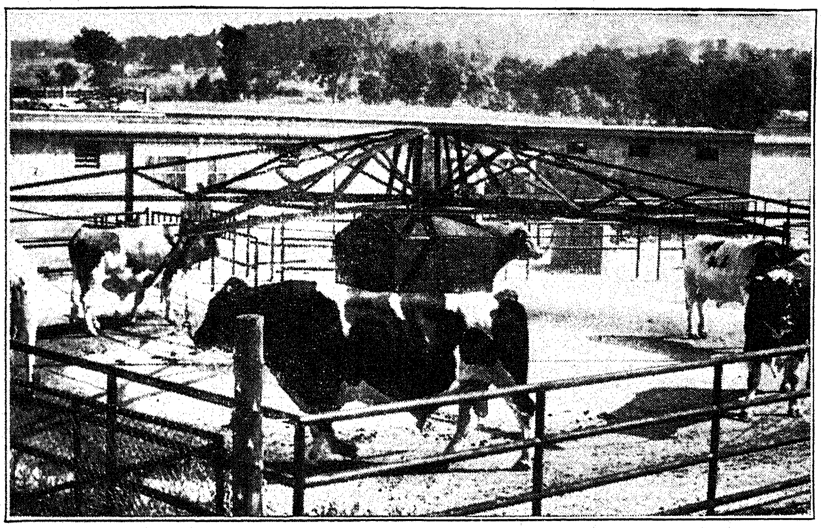
1 per cent iodized salt. This mixture had only 12 per cent total protein. Also, the protein in the mixture would be of poor quality for non-ruminants.

The complex mixture contained corn, oats, linseed meal, soybean oil meal, wheat bran, dehydrated alfalfa, cane molasses, limestone, bone meal, dried brewers' yeast, fish liver oil, irradiated yeast, and a mineral supplement supplying manganese, iron, copper, and cobalt. It thus supplied protein that would be of better quality for non-ruminants, and also contained special calcium, phosphorus, trace mineral, and vitamin supplements.

The bulls did not grow quite so rapidly on this complex concentrate mixture as on the simple one. Also, feeding the complex mixture did not make any appreciable difference in the quality of semen produced. The feed cost for the bulls fed the complex mixture was about 50 per cent greater than for those fed the simple mixture.

New York experiments showed that a deficiency of vitamin A in a ration for mature bulls must be so serious and so long-continued that it will produce decided physical symptoms of the deficiency before semen production is impaired.[112]

In another New York experiment there was no benefit from adding to an ordinary ration for bulls heavily used in artificial insemination, either wheat germ oil as a vitamin E supplement or shark liver oil as a vitamin A supplement.[113] In other experiments there has been no advantage in adding dehydrated young grass or sprouted oats to rations for bulls.[114]



ELECTRIC BULL EXERCISER

In this electric bull exerciser at the New York Dairy Cattle Breeding Center, 6 bulls are exercised at a time. (From New York State College of Agriculture, Cornell University.)

The results of these experiments agree with the results previously summarized that have been secured in experiments with dairy cows and dairy heifers. The data indicate that for dairy cows, heifers, or bulls high-quality protein is not needed in the concentrate mixture when roughage of ordinary good quality is fed. Also, special mineral and vitamin supplements are not needed, unless the roughage is actually deficient in a mineral nutrient or in carotene.

1157. Care of the bull in service.— Except perhaps in unusually cold climates, the best quarters for a bull are a well-built open shed with an adjoining

roomy paddock where he may exercise. This should be constructed as a "safety bull pen," with breeding chute and breeding rack so arranged that the necessity of handling the bull at time of service is eliminated. In such quarters a mature bull, even a vicious one, can be used in safety.

Though this open-air treatment is admirable for the health of the animal, it results in a heavier and rougher coat of hair, and hence breeders offering animals for sale usually prefer to keep the bulls in comfortable box stalls, turning them out only on fair days. Rather than confine the bull in isolation, it is well to have his stall so located and built that he can see the other members of the herd. The hoofs of a bull spending most of his time in the stall need regular trimming.

Louisiana experiments show that continued very hot weather greatly reduced the quality of semen and the fertility of bulls.[115]

It is generally advised that to keep a bull healthy and a sure breeder he should have plenty of exercise. No experimental results are available to show the effects of no exercise in consecutive years upon bulls confined to stalls. In a recent Michigan 6-month test there was no appreciable advantage from exercising confined bulls on a mechanical exerciser daily, except Sundays, but in other experiments exercise has been beneficial.[116]

Some dairymen who have two or more dehorned bulls turn them into one paddock, where they get plenty of exercise tussling with each other. Others exercise the bull on a tread power, where he may run the separator, pump water, do other useful work, or run the power for exercise only. Still others fix a long sweep on a post and tie the bull to it, so he will walk around in a circle.

Another device is a light cable stretched between two high posts, the bull being attached to it by a sliding chain so that he is able to walk back and forth along the cable. Electric bull exercisers, which are motor driven devices that lead bulls in a circular path, are convenient for breeders having several bulls.

From the standpoint of safety it is always desirable to dehorn the bull. Often breeders dislike to do this, because in the opinion of some it detracts from the appearance of the animal. In reaching a decision on this point one should bear in mind that many men have been killed by bulls with horns, who might have otherwise escaped.

A bull should always be handled with a strong, safe staff attached to the ring in his nose. Even with a quiet, peaceable bull, safety lies only in handling him without displaying fear and yet watching him carefully every minute. Nearly all the accidents occur with "quiet" bulls that have been too much trusted.

A good sire should be retained in the herd until it is necessary to make a change to prevent inbreeding. If he has proved to be a desirable sire and if he is still potent, he should be sold to some other breeder. No commoner mistake is made than discarding a likely bull at 3 to 4 years of age, before his heifers have come into milk to demonstrate how valuable a sire he may be.

QUESTIONS

1. State 5 essentials in rations for raising dairy cattle.
2. Discuss the protein requirements of dairy calves, considering both amount and quality of protein.
3. What has been found out concerning the need for fat?
4. State the importance of each of the following minerals for young dairy cattle: (a) Salt; (b) calcium; (c) phosphorus; (d) iodine; (e) other trace minerals.
5. How can the vitamin A needs of dairy calves be readily met?
6. Under what conditions should a vitamin D supplement be fed?
7. Discuss the needs for other vitamins.
8. Has the use of vitamin pills or capsules been beneficial?
9. What have experiments shown concerning the use of (a) antibiotic feed supplements; (b) surfactants; (c) arsonic supplements?
10. Would you use cud inoculation in raising dairy calves?
11. Discuss the importance of water for dairy calves.

12. State the important points in caring for a calf after birth.
13. Discuss the housing of dairy calves.
14. Tell how a dairy calf is started on whole-milk feeding.
15. What is the advantage and the disadvantage of nipple pails?
16. What sort of concentrate mixtures should be used for calves fed whole milk?
17. Discuss the importance of good-quality hay for calves.
18. Discuss the use of silage for calves; of pasture.
19. Describe the method of raising calves on skimmilk, stating the sort of concentrate mixtures that are most economical for feeding with skimmilk.
20. Discuss the use of the following for raising dairy calves; (a) buttermilk; (b) whey; (c) reconstituted milk.
21. Describe the "nurse-cow method" of raising cows.
22. Describe the raising of calves on a dry calf starter and a minimum amount of whole milk.
23. What sort of a formula should be used for a calf starter?
24. What is the advantage of the calf-starter method over the feeding of a gruel?
25. With the present price received for milk in your area, is the use of a milk replacer economical?
26. Discuss the nutrient requirements of dairy heifers.
27. What roughages and what concentrates are used most commonly for heifers in your region? What improvements can you suggest in the usual methods of feeding heifers?
28. Describe: (a) The feeding of heifers from 6 to 12 months of age; (b) the feeding of heifers over one year of age.
29. Discuss the age for first calving of heifers.
30. About how much should a Holstein heifer weigh at 1 year of age; a Jersey heifer?
31. Discuss the cost of raising heifers.
32. How would you select a bull to head a herd of high-producing grade cows?
33. State the most important points in the feed and care of a young bull.
34. Discuss the feed and care of the bull in service.

REFERENCES

1. For a detailed review on the nutrition of calves, see: Savage and McCay, N.Y., The Nutrition of Calves; a Review, Jour. Dairy Sci., 25, 1942, pp. 595–650.
2. Kesler, Ronning, and Knodt, Penn., Jour. Anim. Sci., 10, 1951, pp. 969–974; Bryant, Small, and Burkey, U.S.D.A., Jour. Dairy Sci., 38, 1055, p. 608; Huhtanen, Saunders, and Gall, Jour. Anim. Sci., 10, 1951, pp. 1049–1050.
3. Warner, Bernholdt, Grippin, and Loosli, N.Y., Jour. Dairy Sci., 36, 1953, p. 599; Warner, Grippin, Flatt, and Loosli, N.Y., Jour. Dairy Sci., 38, 1955, p. 605; Flatt, Warner, and Grippin, N.Y., Jour. Anim. Sci., 14, 1955, pp. 1202–1203; see also: Dziuk and Sellers, Minn., Amer. Jour. Vet. Res., 16, 1950, p. 411.
4. Lofgreen, Loosli, and Maynard, N.Y., Jour. Anim. Sci., 10, 1951, pp. 169–183; Ritzman and Colovos, N.H. Tech. Bul. 80; Blaxter and Price, Jour. Agr. Sci., England, 36, 1946, pp. 301–309; see also results of cooperative experiments by several experiment stations, summarized by Armsby and by Forbes: Armsby et al., Bul. of National Res. Council, No. 12; Forbes et al., Bul. of National Res. Council, No. 42. In addition, see: Swett, Eckles, and Ragsdale, Mo. Res. Bul. 66; Nevens, Davis, et al., Nebr. Buls. 181, 184.
5. Blaxter and Wood, Scotland, Brit. Jour. Nutr., 6, 1952, pp. 56–71.
6. Ellenberger, Newlander, and Jones, Vt. Bul. 576; Eckles and Gullickson, Minn., Jour. Agr. Res., 42, 1931, pp. 603–616; Ragsdale, Mo. Buls. 336, 338; Ritzman and Colovos, N.H. Tech. Bul. 80; see also: Fitch and Lush, Kan., Jour. Dairy Sci., 14, 1931, pp. 116–124; Henderson and Anthony, West Va. Bul. 232.
7. Lambert, Allen, Jacobson, and Ward, Iowa, Jour. Anim. Sci., 13, 1954, p. 991; Cunningham and Loosli, N.Y., Jour. Dairy Sci., 37, 1954, pp. 453–461; see also: Gullickson, Fountaine, and Fitch, Minn., Jour. Dairy Sci., 25, 1942, pp. 117–128; Arrington and Reaves, Va., Jour. Dairy Sci., 31, 1948, pp. 1–9.
8. Mather, Bender, and Pfau, N.J. Rpt. 1949; Hart and Elvehjem, Wis. Bul. 410; Knoop, Krauss, Sutton, and Washburn, Ohio Bimo. Bul. 188.
9. Thomas, Okamoto, Jacobson, and Moore, U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 805–812.
10. Converse, Kane, and Meigs, U.S.D.A., Jour. Dairy Sci., 23, 1940, pp. 566–567.
11. Ellenberger, Newlander, and Jones, Vt. Buls. 570, 576; Archibald and Bennett, Mass., Jour. Agr. Res., 51, 1935, pp. 83–96; Huffman et al., Mich. Tech. Bul. 134; Huffman et al., Jour. Dairy Sci., 16, 1933, pp. 203–223; Lamb et al., Mich., Jour. Dairy Sci., 17, 1934, pp. 233–241; Jones, Haag, and Brandt, Ore. Bul. 329; Henderson and Weakley, West Va. Bul. 231; Van Landingham, Henderson, and Bowling, West Va., Jour. Dairy Sci., 18, 1935, pp. 557–572.
12. Jones, Eckles, and Palmer, Minn., Jour. Dairy Sci., 9, 1926, pp. 119–139; Bechdel, Honeywell, and Dutcher, Penn. Bul. 230; Kuhlman, Gallup, and Weaver, Okla., Jour. Dairy Sci., 18, 1935, pp. 433–434.
13. Gullickson and Fitch, Minn., Jour. Dairy Sci., 27, 1944, pp. 331–335; Krauss, Monroe and Hayden, Ohio Spec. Cir. 57; Ore. Bul. 329; Keyes, Bechdel, and Thorp, Penn., Jour. Dairy Sci., 26, 1943, pp. 741–743.
14. Nelson and Cunningham, New Mex. Bul. 333; New Mex. Rpt. 1952.

15. Eaton, Spielman, Johnson, and Matterson, Conn., Jour. Dairy Sci., 32, 1949, p. 711.
16. Rousseau et al., Conn. and U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 889–899; see also: Ward, Bechdel, and Guerrant, Penn., Jour. Dairy Sci., 23, 1940, pp. 115–124; Lundquist and Phillips, Wis., Jour. Dairy Sci., 27, 1944, pp. 651–652.
17. Loosli, Becker, Huffman, Phillips, and Shaw. Nutrient Requirements of Domestic Animals, III, Nutrient Requirements of Dairy Cattle, 1956.
18. Guilbert, Howell, and Hart, Cal., Jour. Nutr., 19, 1940; pp. 91–103; Moore, Berry, and Sykes, Md. and Mich., Jour. Nutr., 26, 1943, pp. 649–658; Moore, Mich., Jour. Dairy Sci., 22, 1939, pp. 803–811; Kuhlman and Gallup, Okla., Jour. Anim. Sci., 1, 1942, pp. 67–68; Keener, Bechdel, Guerrant, and Thorp, Penn., Jour. Dairy Sci., 25, 1942, pp. 571–583; Moore, Sykes, Jacobson, and Wiseman, U.S.D.A., Jour. Dairy Sci., 31, 1948, pp. 533–538.
19. Md. Rpt. 1944.
20. Huffman, Mich. Quar. Bul., 14, 1931, No. 1 and Mich. Rpt. 1930–32; Bechdel, Landsburg, and Hill, Penn. Bul. 291; Rupel, Bohstedt, and Hart, Wis. Res. Bul. 115.
21. Huffman and Duncan, Mich., Jour. Dairy Sci., 18, 1935, pp. 511–526.
22. Gullickson and Eckles, Minn., Jour. Dairy Sci., 10, 1927, pp. 87–94; S.D. Rpts. 1931, 1932; Morrison and Rupel, Wis. Bul. 396.
23. Hibbs, Krauss, Monroe, and Pounden, Ohio Bimo. Bul. 232.
24. Rpt. of Chief of Bureau Dairy Indus., U.S.D.A., 1952; see also: Bechdel, Hilston, Guerrant, and Dutcher, Penn. Bul. 364; Long, Huffman, and Duncan, Mich. Rpt. 1936–38.
25. Kesler and Knodt, Penn., Jour. Dairy Sci., 33, 1950, p. 381; 34, 1951, p. 506.
26. Hilton, Hauge, Waugh, and Wilbur, Ind. Rpt. 1944; Eckles et al., Minn., Jour. Dairy Sci., 7, 1924, pp. 421–439; Newman, N.Y., Jour. Dairy Sci., 21, 1938, pp. 161–167; Norton and Eaton, N.Y. (Cornell) Bul. 835.
27. Wiese, Johnson, Mitchell, and Nevens, Ill., Jour. Dairy Sci., 30, 1947, pp. 87–94; Bechdel, Eckles, and Palmer, Minn., Jour. Dairy Sci., 9, 1926, pp. 409–438.
28. Wiese, Johnson, and Nevens, Ill., Proc. Soc. Exptl. Biol. Med., 63, 1946, p. 521; Johnson, Hamilton, Nevens, and Boley, Ill., Jour. Nutr., 35, 1948, pp. 137–145; Johnson, Nevens, and Mitchell, Ill., Jour. Dairy Sci., 34, 1951, p. 506; Hopper and Johnson, Ill., Jour. Nutr., 56, 1955, pp. 303–309; Warner and Sutton, Ohio, Jour. Dairy Sci., 31, 1948, pp. 976–985.
29. Thurston, Eckles, and Palmer, Minn., Jour. Dairy Sci., 9, 1926, pp. 37–49; 12, 1929, pp. 394–404.
30. Phillips, Lundquist, and Boyer, Wis., Jour. Dairy Sci., 24, 1941, pp. 977–982; Lundquist and Phillips, Wis., Jour. Dairy Sci., 26, 1943, pp. 1023–1030.
31. Nevens and Kendall, Ill., Jour. Dairy Sci., 30, 1949, pp. 175–181; Md. Rpt. 1945; Gilmore, Jones, Kanegis, and Roepke, Minn., Jour. Amer. Vet. Med. Assoc., 110, 1947, pp. 390–392; Skaggs, New Mex. Bul. 376; Spielman et al., N.Y., Amer. Jour. Vet. Res., 9, 1948, pp. 26–29; Hibbs and Krauss, Ohio Bul. 673; Erb, Scott, Norton, and Morrow, Wash., R.I., and N.H., Jour. Anim. Sci., 8, 1949, pp. 425–432; Wyo. Rpt. 58.
32. Reaves and Cannon, Iowa, Jour. Dairy Sci., 19, 1936, p. 436; N.J. Rpt. 1930; Dahlberg and Maynard, N.Y., Jour. Dairy Sci., 20, 1937, pp. 59–61; Insko and Rupel, Wis. Bul. 405; Isaachsen, Jour. Agr. Sci., England, 22, 1932, pp. 460–484.
33. For a review of the investigations on antibiotic feed supplements for calves and other ruminants, see: Reid, Warner, and Loosli, N.Y., Jour. Agr. and Food Chem., 2, 1954, pp. 186–192. See also: Gaunya, Mochrie, Johnson, and Dembiczak, Conn., Jour. Dairy Sci., 38, 1955, pp. 1–5; MacFadden and Richards, Del., Jour. Dairy Sci., 38, 1955, p. 621; Marshall, Dix Arnold, and Wing, Fla. Rpts. 1952, 1953; Morrison and Deal, Ga., Jour. Anim. Sci., 10, 1951, p. 1057; Owen, Voelker, Jacobson, and Allen, Iowa, Jour. Dairy Sci., 38, 1955, pp. 891–900; Jacobson, McGilliard, and Allen, Iowa, Jour. Anim. Sci., 14, 1955, p. 1210; Bartley, Fountaine, Atkeson, and Fryer, Kan., Jour. Dairy Sci., 36, 1953, pp. 103–111; Bartley, Atkeson, Fryer, and Fountaine, Kan., Jour. Dairy Sci., 37, 1954, pp. 259–268; Bartley, Fountaine, Atkeson, and Fryer, Kan., Jour. Dairy Sci., 37, 1954, pp. 982–989; Bartley et al. Kan., Jour. Dairy Sci., 38, 1955, pp. 1257–1263; Lassiter et al., Ky. Bul. 624; Rusoff and Haq, La., Jour. Anim. Sci., 10, 1951, pp. 331–334; Rusoff et al., La., Jour. Dairy Sci., 37, 1954, pp. 488–497; Rusoff, Stone, Cummings, and Frye, La., Jour. Dairy Sci., 38, 1955, p. 622; Landagora, Rusoff, and Crown, La., Jour. Dairy Sci., 38, 1955, p. 621; Edgerly, Me., Jour. Dairy Sci., 36, 1953, p. A145; Ellsworth, Huffman, Smith, and Ralston, Mich. Quar. Bul., 36, 1953, No. 1; Matsushima, Nebr. Cattle Prog. Rpt. 209; Warner, N.Y., Proc. 1955 Cornell Nutr. Conf.; Hogue, Warner, Loosli, and Grippin, N.Y., Jour. Anim. Sci., 14, 1955, p. 1209; Williams and Jensen, N.D., Jour. Anim. Sci., 13, 1954, p. 1004; Hibbs, Conrad, and Pounden, Ohio, Jour. Dairy Sci., 36, 1953, pp. 1319–1325; 37, 1954, pp. 724–736; Ronning, Richardson, Berousek, and Norton, Okla. Tech. Bul. T-52; Kesler, Penn., Jour. Anim. Sci., 13, 1954, pp. 10–19; Knodt, Ross, and Stein, Penn., Jour. Dairy Sci., 36, 1954, pp. 1201–1204; Swanson, Hinton, and McLaren, Tenn., Jour. Dairy Sci., 38, 1955, pp. 1385–1389; Pritchard, Riddell, and Durrell, Vt., Jour. Dairy Sci., 37, 1954, p. 654; Pritchard et al., Vt., Jour. Anim. Sci., 14, 1955, pp. 336–339, 1011–1014; Kon, Oliver, Porter, and Ridler, England, Proc. British Nutr. Soc., 12, 1953, p. X.
34. Voelker and Jacobson, Iowa, Jour. Dairy Sci., 36, 1953, pp. 592–593; Voelker, Allen, Jacobson, and Blake, Iowa, Jour. Dairy Sci., 37, 1954, pp. 737–743; Lassiter, Denton, and Bastin, Ky., Jour. Dairy Sci., 36, 1953, p. 592; 38, 1955, pp. 407–415; Lassiter, Denton, and Rust, Ky., Jour. Anim. Sci., 14, 1955, pp. 760–768.
35. Owen and Allen, Iowa, Jour. Dairy Sci., 37, 1954, p. 654; Graf and Holdaway, Va., Jour. Dairy Sci., 35, 1952, p. 492; Graf and Fisher, Va. Rpt. 1950–53.
36. Pounden, Hibbs, et al., Ohio, Jour. Dairy Sci., 31, 1948, pp. 1041–1050; 32, 1949, pp. 1016–1931; 33, 1950, pp. 585–592; 33, 1950, pp. 639–644; 36, 1953, pp. 1326–1334; 38, 1955, p. 608.
37. Pounden, Conrad, and Hibbs, Ohio, Jour. Amer. Vet. Med. Assoc., 124, 1954, pp. 394–

396; see also: Williams and Jensen, N.D., Jour. Anim. Sci., 13, 1954, pp. 1004.
38. Davis, Autrey, Herlich, and Hawkins, Ala. and U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 562–570; Pelissier, Slack, Trimberger, Turk, and Loosli, N.Y. Farm Res., 20, 1954, No. 2; McGilliard, Ronning, Berousek, and Norton, Okla., Jour. Dairy Sci., 35, 1952, p. 493; Tenn. Rpt. 1951; Ackerman and Fike, West Va., Jour. Dairy Sci., 38, 1955, p. 608; Grimberger, Holland, Mededling, uit Stichting Instituut voor Moderne Veeroeding, S 42.
39. Morrison, Hulce, and Humphrey, Wis. Bul. 352; Rupel, Wis. Bul. 404.
40. Atkeson, Warren, and Anderson, Id., Jour. Dairy Sci., 17, 1934, pp. 249–256.
41. Moll, Brandly, McNutt, and Harris, Wis. Bul. 500.
42. Segard, Holstein Friesian World, Oct. 16, 1954; Christian, Cornell Veterinarian, 42, 1952, pp. 16–21.
43. Dickey and Waller, Vt. Exten. Cir. 114; see also: La. Rpt. 1949.
44. Davis, Autrey, Herlich, and Hawkins, Ala. and U.S.D.A., Jour. Dairy Sci., 37, 1954, pp. 562–570.
45. Fourt, Idaho, Farm Journal, Apr. 1954; Esmay, Williams, and Guyer, Mo. Res. Bul. 527; Murley, Culvahouse, and Waugh, N.C., Jour. Dairy Sci., 37, 1954, pp. 656–657; Erb et al., Wash. Tech. Bul. 3.
46. Ragsdale, Brody, and Nelson, Mo. Buls. 210, 228.
47. Gauyna, Mochrie, Eaton, and Johnson, Conn., Jour. Dairy Sci., 37, 1954, p. 655; Burch and Frye, La. Rpt. 1952; Keyes, Peace, and Brence, Mont., Jour. Dairy Sci., 37, 1954, p. 655; Kaeser and Sutton, Ohio, Jour. Dairy Sci., 31, 1948, pp. 523–532; Allen, Vt. Bul. 544; Jacobson, Converse, Wiseman, and Moore, U.S.D.A., Jour. Dairy Sci., 34, 1951, pp. 905–910; Payne, Scotland, Scot. Agr., 32, 1953, pp. 186–189.
48. Wise, Miller, and Anderson, S.C. Rpt. 1942; Tretsven, Mont. Cir. 187.
49. Shaw and Atkeson, Kan. Rpt. 1940–42.
50. Calloway, La. Bul. 180.
51. Rupel, Wis. Bul. 404.
52. Hilton, Wilbur, and Heinton, Ind. Bul. 373; McCandlish, Iowa Res. Bul. 51; Kildee, Iowa Cir. 16; Otis, Kan. Bul. 126; S.C. Rpt. 1924; Fain and Jarnagin, Va. Bul. 172; Ireland Dept. Agr. and Tech. Instr. Jour., 20, 1920, pp. 201–204.
53. Hibbs, Pounden, and Conrad, Ohio, Jour. Dairy Sci., 36, 1953, pp. 717–727; Blaxter, Hutcheson, Robertson, and Wilson, Scotland, British Jour. Nutr., 6, 1952, pp. i–ii.
54. Hibbs and Pounden, Ohio Bul. 725.
55. Morrison, Hulce, and Humphrey, Wis. Bul. 362; Morrison and Rupel, Wis. Bul. 396; Rupel, Wis. Bul. 404.
56. Norton, N.Y., Jour. Dairy Sci., 29, 1946, pp. 546–547.
57. Musgrave, Williams, Norton, and Gallup, Okla. Bul. B-443.
58. Sykes, Converse, and Moore, U.S.D.A., Jour. Dairy Sci., 38, 1955, pp. 1246–1256.
59. Ellenberger, Newlander, and Jones, Vt. Buls. 564, 570, 576.
60. Jacobsen, Ark. Bul. 318.
61. Dolge et al., Conn., Jour. Dairy Sci., 35, 1952, pp. 424–435; 36, 1953, pp. 235–245; Hibbs, Conrad, and Vandersall, Ohio, Jour. Anim. Sci., 14, 1955, p. 1208.
62. Eaton et al., Conn. and U.S.D.A., Jour. Dairy Sci., 34, 1951, pp. 124–135; Gardner and Ackers, Ill., Hoard's Dairyman, Dec. 10, 1954.
63. Keener et al., N.H. Bul. 402; N.H. Cir. 77.
64. Porter and Kesler, Penn., Jour. Anim. Sci., 13, 1954, pp. 1010–1011.
65. Headley, Nev. Rpt. 1949; Henderson and Norton, R.I. Bul. 311; Wilson and Bartle, S.D. Farm and Home Res., 5, 1953, No. 1.
66. Grinnells, N.C. Res. and Farming, 9, 1950, Prog. Rpt. 1; Grinnells and Moore, N.C. Rpt. 1951.
67. McCullough, Ga., Jour. Anim. Sci., 14, 1955, p. 1239.
68. Tomhave and Baker, Del. Cir. 14; Spitzer and Carr, Ind. Bul. 246; Krauss and Crawford, Ohio Bimo. Bul. 137; Ellington and Knott, Wash. Bul. 178; Morrison and Rupel, Wis. Bul. 388; Rupel, Wis. Bul. 404; Canada Expt. Farms, Kentville, N.S., Station, Rpt. of Supt. 1922.
69. Dracy and Bartle, S.D. Farm and Home Res., 1, 1950, No. 1.
70. Converse, U.S.D.A. Cir. 822.
71. Morrison and Rupel, Wis. Bul. 362.
72. Otis, Kan. Bul. 126; Krauss and Monroe, Ohio Bimo. Bul. 241.
73. Jacobson, Cannon, and Thomas, Iowa, Jour. Dairy Sci., 32, 1949, pp. 418–434; Murley, Jacobson, Wise, and Allen, Iowa, Jour. Dairy Sci., 32, 1949, pp. 609–619; Barker, Wise, and Jacobson, Iowa, Jour. Dairy Sci., 35, 1952, pp. 507–514; Gullickson, Adams, Gander, and Sauter, Minn., Jour. Dairy Sci., 36, 1953, pp. 599–600; Jarvis and Waugh, N.C., 32, 1949, pp. 665–670.
74. Gullickson, Minn. Farm and Home Sci., 8, 1950, No. 1; Herman and Ragsdale, Mo., Jour. Dairy Sci., 22, 1939, pp. 454–455.
75. Brown, Read, and Willard, Wyo., Jour. Dairy Sci., 35, 1952, pp. 491–492.
76. Weaver, Shay, and Ely, Iowa Cir. 91; Berry, Md. Bul. 330; Kuhlman, McGilliard, and Weaver, Okla. Rpts. 1930–32, 1932–34; Hinton, Tenn. Rpt. 1949.
77. Johnson, N.Y. State Vet. Col. Rpt. 1946.
78. Savage and Crawford, N.Y. (Cornell) Bul. 622; Norton and Eaton, N.Y. (Cornell) Bul. 835; Newman and Savage, N.Y., Jour. Dairy Sci., 21, 1938, pp. 161–167; Turk and Burke, N.Y. (Cornell) Exten. Bul. 761; Warner, N.Y., Proc. 1955 Cornell Nutr. Conf.
79. Alaska Rpt. 1938–41; Henke and Morita, Hawaii Prog. Note 80; Atkeson and Warren, Id. Buls. 192, 197; Hulce and Nevens, Ill. Cir. 202; Riddell, Kan. Rpt. 1932–34; Snell, La. Rpt. 1929–31; Ingham, Meade, and Berry, Md. Bul. 319; Berry, Md. Buls. 330, 354; Md. Rpts. 1943, 1944; Lindsey and Archibald, Mass. Buls. 271, 280, 293; Mich. Rpt. 1928–30; Eckles and Gullickson, Minn. Bul. 215; Ragsdale and Turner, Mo. Buls. 179, 189, 210; Herman et al., Mo. Bul. 556; Tretsven, Mont. Cir. 169; Trimberger and Davis, Nebr. Res. Bul. 134; Morrow, Keener, et al., N.H. Bul. 354; Cunningham and Nelson, New Mex. Bul. 318; Krauss, Monroe, and Hayden, Ohio Buls. 497, 516, 532, 548, Ohio Bimo. Bul. 173; Hibbs and Pounden, Ohio Bul. 725; Jones, Brandt, and Wilson, Ore. Bul. 290; Bechdel and Williams, Penn. Buls. 213, 243, 266; Elting and LaMaster, S.C. Bul. 293; Copeland and Darnell, Tex. Rpt. 1941; Knott, Hodgson, and Ellington, Wash. Bul.

273; Morrison and Rupel, Wis. Bul. 388; Rupel and Bohstedt, Wis. Bul. 410.

80. Brown, Lassiter, and Rust, Ky., Jour. Dairy Sci., 38, 1955, p. 620.
81. Gardner, Ill., Jour. Dairy Sci., 35, 1952, p. 491; Lambert, Jacobson, Allen, and Bell, Iowa, Jour. Dairy Sci., 38, 1955, pp. 6–12; Norton and Eaton, N.Y. (Cornell) Bul. 835; Morrow, Keener, and Teeri, N.H. Bul. 363; see also: Skaggs, N. Mex. Bul. 351.
82. Fountaine, Kan. Rpt. 1948–50.
83. Fountaine, Kan. Rpt. 1948–50; Lassiter, Denton, Brown, and Rust, Ky., Jour. Dairy Sci., 38, 1955, pp. 1242–1245; Md. Rpt. 1944; Savage and Newman, N.Y. (Cornell) Rpt. 1938; Norton and Eaton, N.Y. (Cornell) Bul. 835.
84. Rusoff, Alford, and Hyde, La., Jour. Dairy Sci., 36, 1953, pp. 39–44.
85. Morrison and Rupel, Wis. Bul. 388; Rupel, Wis. Bul. 404.
86. Young, Iowa, Jour. Dairy Sci., 36, 1953, p. 600; Flipse, Huffman, Duncan, and Webster, Mich., Jour. Dairy Sci., 33, 1950, pp. 557–563; Noller and Huffman, Mich., Proc. 10th Distillers Feed Conf., 1955; Mather, Bender, and Garey, N.J. Rpt. 1949; Wallace, Loosli, and Turk, N.Y., Jour. Dairy Sci., 34, 1951, pp. 256–264; Jarvis, Waugh, and Murley, N.C., Jour. Anim. Sci., 11, 1952, pp. 766–767; Williams and Jensen, N.D. Bimo. Bul., 17, 1955, Nos. 3, 5; Williams and Knodt, Penn., Jour. Dairy Sci., 32, 1949, pp. 986–992; 33, 1950, pp. 809–814; Knodt et al., Penn., Jour. Dairy Sci., 35, 1952, pp. 675–678; 37, 1954, pp. 373–379, 655–656; Leighton and Rupel, Tex. Prog. Rpt. 1710.
87. Wallace, Loosli, and Turk, N.Y., Jour. Dairy Sci., 34, 1951, pp. 256–264.
88. Allen, Wis., Hoard's Dairyman, Feb. 25, 1955; Holstein Friesian World, July 2, 1955.
89. Nevens, Ill., Jour. Dairy Sci., 2, 1919, pp. 435–443; McCandlish, Iowa Res. Bul. 51; McCandlish, Iowa, Jour. Dairy Sci., 6, 1923, pp. 572–587; 7, 1924, pp. 160–162; Tretsven, Mont. Bul. 282; S.C. Rpt. 1924; Olson, S.D. Bul. 236; Henderson and Anthony, West Va. Bul. 232.
90. Herman, Ragsdale, and Stallcup, Mo. Bul. 584; Herman, Ragsdale, and Bower, Mo. Bul. 621; Reid, N.Y., Proc. 1953 Cornell Nutr. Conf.; Sorenson, Bratton, Hansel, and Hough, N.Y., Jour. Anim. Sci., 13, 1954, pp. 1031–1032; Swanson and Spann, Tenn., Jour. Anim. Sci., 13, 1954, p. 1032; Crichton and Aitken, Scotland, Proc. British Nutr. Soc., 13, 1954, pp. 10–16; Bartlett, England, Proc. British Nutr. Soc., 13, 1954, p. 17; Bonnier, Hansson, and Skjervold, Sweden, Acta Agr. Suec., 3, 1948, p. 1; Hansson, Brännäng, and Claesson, Acta Agr. Scand., 3, 1953, p. 61; Filmer, Rpt. Dept. Agr., New Zealand, 1952, p. 8; Hansen and Steensberg, Denmark, Beretn. Forsoogslab, No. 246, 1950.
91. Harrison, N.Y. (Cornell) Exten. Bul. 596; see also: Pratt, Hibbs, and Knoop, Ohio Bul. 695.
92. Morrison and Hulce, Wis., unpublished data.
93. Harrison and Kahn, N.Y. (Cornell) Rpt. 1931.
94. Kan. Rpt. 1926–28; Grinnells and Moore, N.C. Res. in Farming, 8, 1950, No. 4; Hunt, Va. Buls. 219, 225.
95. Woll, Cal., Jour. Dairy Sci., 1, 1917, pp. 447–461; Id. Buls. 131, 149, 164, 179; Ind. Rpt. 1925; Reed, Fitch, and Cave, Kan. Bul. 233; Eckles, Mo. Bul. 158; Eckles and Swett, Mo. Bul. 163; Nevens and Davis, Nebr. Bul. 181; Headley, Nev. Rpt. 1933; Bender and Bartlett, N.J. Cir. 263; Monroe, Ohio Bul. 673; Ore. Rpt. 1920–22; LaMaster, S.C. Rpt. 1926; Shepherd and Miller, U.S.D.A. Farmers' Bul. 1723; see also: Harshbarger and Salisbury, Jour. Dairy Sci., 32, 1949, pp. 715–716.
96. Reid et al., N.Y., Jour. Dairy Sci., 38, 1955, pp. 20–28; Morrison and Deal, Ga. Rpt. 1951.
97. N.J. Rpts. 1940, 1944; Ore. Bul. 461; Tenn. Rpt. 1950; Hodgson, Knott, Miller, and Murer, Wash. Bul. 366; Hodgson, Knott, [illegible] Wolberg, Western Wash. Sta. Rpt. [illegible] Willard, Wyo., Jour. Dairy Sci., 21, [illegible] pp. 153–160.
98. Ga. Rpt. 1946; Nevens and Howerter, [illegible] Jour. Dairy Sci., 34, 1951, pp. 508; Tenn. Rpt. 1951.
99. Turk and Burke, N.Y. (Cornell) Exten. Bul. 761.
100. Chapman and Dickerson, Wis. Bul. 438; Dickerson and Chapman, Wis., Amer. Soc. Anim. Prod., Proc. 1940; see also: Kearl, N.Y., Hoard's Dairyman, Dec. 25, 1953.
101. Eckles, Mo. Res. Bul. 36; Ragsdale, Mo. Bul. 336; Espe, Cannon, and Hansen, Iowa Res. Bul. 154; Fitch, Kan., mimeo. rpt.; Davis, Nebr., information to the author; Elting and LaMaster, S.C. Bul. 293; Henderson, West Va., information to the author; Bowling, West Va., Jour. Dairy Sci., 26, 1943, pp. 47–52; Moseley, Stuart, and Graves, U.S.D.A. Tech. Bul. 116; see also: Ariz. Rpts. 1941, 1942; Matthews and Fohrman, U.S.D.A. Tech Buls. 1098, 1099.
102. Swett, Book, Matthews, and Fohrman, U.S.D.A. Tech. Bul. 1111.
103. Cunningham, N.Y. (Cornell) Bul. 807; Ahalt and Hamilton, Md. Bul. A-17; Hayden, Ohio Bul. 289; Staples and Lush, La. Bul. 342; Selby and Kuhlman, Ore. Bul. 324; Stallcup, Herman, and Ragsdale, Mo. Bul. 523; see also: Hulce and Nevens, Ill. Cir. 202; Dow, Me. Buls. 361, 385; Watkins, Md. Bul. 356; Ragsdale, Mo. Bul. 338; Grinnell, N.H. Bul. 302; Greene, N.C. Res. in Farming, 3, 1944, No. 1; Eke, West Va. Bul. 224; McNall and Mitchell, Wis., Bul. 405.
104. Bratton, N.Y., Proc. 1953 Cornell Nutr. Conf.; Flipse, Snyder, Thacker, and Almquist, Penn., Prog. Rpt. 104.
105. Hodgson, Hall, Sweetman, Wiseman, and Converse, U.S.D.A., Jour. Dairy Sci., 29, 1946, pp. 669–687; see also: Erb, Andrews, Hauge, and King, Ind., Jour. Dairy Sci., 30, 1947, pp. 687–702; Miss. Farm Res., 5, 1942, No. 9; Jones and Haag, Ore., Jour. Dairy Sci., 27, 1944, pp. 632–633.
106. Branton, Bratton, and Salisbury, N.Y., Jour. Dairy Sci., 30, 1947, pp. 1003–1013.
107. Flipse, Snyder, Thacker, and Almquist, Penn., Jour. Dairy Sci., 35, 1952, pp. 949–956; Quicke, Phillips, and Dreher, Wis., Jour. Dairy Sci., 33, 1950, pp. 870–877; see also: Henderson and Norton, R.I. Bul. 311.
108. Autrey, Alston, and Buckalew, Ala. Rpt. 60–61; Branton, Patrick, Newsom, and D'Arensbourg, La., Jour. Dairy Sci., 36, 1953, pp. 199–204; Swanson, Tenn. Rpt. 1953.
109. Smirnov-Ugrjumov, Probl. Zivotn., 1937, No. 3, p. 43; Smirnov-Ugrjumov and Laptev, Probl. Zivotn., 1938, No. 2, pp. 64–72.

(Abstr. in Anim. Breeding Abstracts, 5, 1937, p. 401; 6, 1938, p. 293). See also: Knoop, Ohio Bul. 659.

110. Branton, Bratton, and Salisbury, N.Y., Jour. Dairy Sci., 32, 1949, pp. 292–300; see also: Flipse, Almquist, and Johnson, Penn., Jour. Dairy Sci., 39, 1956, pp. 60–65.

111. Reid, Ward, and Salsbury, N.J., Jour. Dairy Sci., 31, 1948, pp. 429–437.

112. Bratton et al., N.Y., Jour. Dairy Sci., 31, 1948, pp. 779–791.

113. Salisbury, N.Y., Jour. Dairy Sci., 27, 1944, pp. 551–562; Salisbury, VanDemark, and Elliott, N.Y. (Cornell) Rpt. 1944.

114. Flipse and Almquist, Penn., Jour. Dairy Sci., 37, 1954, pp. 1123–1127; Weatherby, Reece, and Bartlett, N.J. Amer. Soc. Anim. Prod., Proc. 1940.

115. Johnston and Branton, La., Jour. Dairy Sci., 36, 1953, pp. 934–942; Patrick et al., La., Jour. Dairy Sci., 13, 1954, p. 1028.

116. Snyder and Ralston, Mich., Jour. Dairy Sci., 38, 1955, pp. 125–130; Woodward, Wash. Bul. 158; Ellington, Wash., Buls. 175, 196; Hamilton and Symington, Canadian Jour. Comp. Med., 3, 1939, p. 337; see also: Lepard, Shuart, and Foster, N.J., Jour. Dairy Sci., 24, 1941, p. 509.

CHAPTER XXVIII

GENERAL PROBLEMS IN BEEF PRODUCTION

I. Nutrient Requirements of Beef Cattle

1158. Modern beef production requires scientific feeding.—Beef cattle in this country must now be fed more scientifically than a generation ago, because most of those fattened for our markets are much younger. Since they are still growing rapidly in protein tissues and skeleton, they need a more liberal supply of protein and minerals than do older cattle. Also, they are more apt to suffer from a lack of vitamins. In these modern methods of beef production, scientific feeding is necessary to avoid deficiencies and to secure efficient results.

Years ago, beef cattle were commonly raised to the age of 2 or 3 years before they were fattened for market. They made most of their growth on cheap pasture and were usually carried through the winters on roughage without any concentrates whatsoever. These well-grown cattle, 2 years old or more, were brought from the western ranges or other pasture districts to sections of the country where grain was cheaper, and there fattened for market.

Now, the cattle raised for beef on farms in the corn belt and eastward are generally fattened as they grow. Such cattle are fattened for marketing at 10 to 18 months of age as "baby beeves" or "fat yearlings." Some are even sold for slaughter at weaning time or soon afterwards as "heavy fat calves."

On the western ranges, where three-fourths of our beef cattle are produced, a considerable proportion of the calf crop is now marketed as feeder calves. These are fattened for market in the corn belt and other grain-growing regions by one of the methods described later. Except for the heifers needed for replacements in the breeding herds, most of the rest of the young cattle in the range districts are sold as yearlings in the fall of the following year, instead of being grown under range conditions to 2 years of age or more.

The pronounced change in the age at which beef cattle are marketed for slaughter has come about because of two factors: First, consumers desire rather small cuts of beef and want beef which is tender and has a minimum of waste fat. Second, as is shown later in this chapter, cattle fattened when young produce much more economical gains than those which are older. (1195)

1159. Nutrient requirements of various classes of cattle.—Before discussing in detail the requirements of beef cattle for the various nutrients, let us consider the differences in the general requirements for the various classes of beef cattle.

The nutrient needs of beef breeding cows are far different from those of dairy cows, for their milk yields are much lower. Also, they are usually dry during the winter and produce their milk while on pasture. It is shown in the next chapter that beef cows may be wintered entirely on roughage, if it is of fairly good quality and if enough legume forage is fed to meet their limited need for protein. (1211) Normally, beef cows need no concentrates during the pasture period.

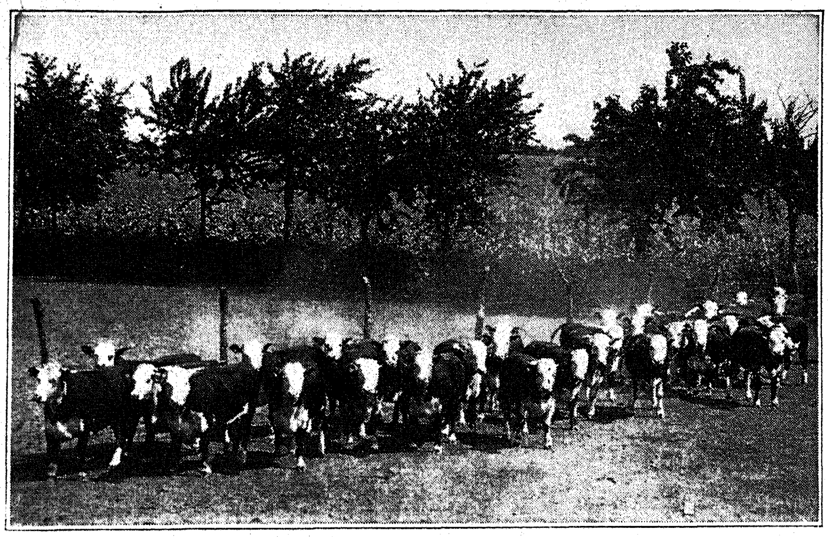
When calves or yearlings are being carried through the winter to be fattened later, they may likewise be fed entirely or chiefly on roughage, if it is of good quality. As is shown in the next chapter, whether or not it will be profitable to feed grain in addition to good roughage will depend on the method of fattening that is to be followed.

The requirements for fattening cattle are much different from those for breeding cows or for wintering young stock. To enable fattening cattle to make rapid

gains, they must receive rations rich in digestible nutrients and net energy. Except when grain is unusually high in price compared with roughage, a liberal amount of grain should generally be fed to cattle being fattened in dry lot. Unless this is done, they will make less rapid gains and will not reach as good a finish. Especially with calves and yearlings, good gains cannot be expected unless the ration provides ample protein, minerals, and vitamins.

carotene needed per head daily by the various classes of beef cattle.

As a guide in selecting efficient rations for the different classes of beef cattle, example rations, adapted to various conditions, are given in Appendix Table VII. In the paragraphs which immediately precede the example rations in this table, the changes are indicated which can be made to adapt the rations to local conditions. Additional information concerning desirable rations for various



YOUNG CATTLE NEED AMPLE PROTEIN, MINERALS, AND VITAMINS

Cattle fattened for market when young need a much more liberal supply of protein, minerals, and vitamins than do older cattle.

classes of beef cattle is given in Chapter XXIX.

1160. Feeding standards and example rations.—The nutrient requirements of beef cattle of the various ages and classes are shown in the feeding standards presented in Appendix Table III. These state the amounts of dry matter, digestible protein, and total digestible nutrients recommended per head daily for cattle of various weights. For the computation of rations on the net energy basis, net-energy recommendations are also given. These net-energy figures are not used when rations are computed on the basis of total digestible nutrients. The standards also include the amounts of calcium, phosphorus, and

The recommendations made in the feeding standards presented in this volume are based chiefly on studies by the author of the many experiments conducted by the American experiment stations to study the requirements of beef cattle. Careful consideration has also been given to the recommendations made by a special committee of the National Research Council in their report on "Recommended Nutrient Allowances for Beef Cattle."[1]

In the report of this committee the amounts of feed recommended per head

daily are given in terms of air-dry feed, instead of dry matter. The author prefers to state the allowances in terms of dry matter, because of the considerable differences in dry-matter content of such feeds as hay or cured fodder in humid and semi-arid districts. Also, in the report of this committee, a range is not indicated in the requirement for the various nutrients. For the reasons that have been pointed out previously, the author prefers to show a range in the amounts of dry matter, digestible protein, and total digestible nutrients or net energy. (317)

1161. Amounts of protein required.—Numerous experiments have proved that fattening cattle and other beef cattle do not need nearly so much protein as was recommended in the Wolff-Lehmann and other old feeding standards. This fact is of great financial importance in beef production, because protein supplements ordinarily cost much more per ton than grain.

Many feeding trials have been conducted by the experiment stations to find whether or not a protein supplement is needed to balance various rations for fattening cattle. In other experiments the results have been determined from feeding different amounts of protein supplements in practical rations for fattening cattle. Less information is available concerning the protein requirements for beef breeding cows or for wintering young beef cattle. Because of the limitations of space, the many experiments bearing on the protein requirements cannot be reviewed here. Only certain general conclusions can be given.

The amounts of protein recommended in the Morrison standards are based chiefly on studies by the author of the experiments on this subject. These include trials over several years by the author and associates to determine the protein requirements for fattening yearling cattle.[2]

No smaller amounts of digestible protein are recommended in these standards than have actually been proven to give good results under practical farm conditions. In certain other feeding standards for beef cattle, smaller amounts of protein have been recommended for some classes of cattle, largely on theoretical grounds rather than on the results of actual feeding requirements. The author prefers to follow a conservative policy in all feeding standard recommendations and to base his advice on the results of experiments conducted under practical conditions.

Feeding somewhat less protein to fattening animals than advised in the standards will not produce any serious effects. It may even be economical when protein supplements are very expensive, in comparison with grain. It is believed, however, that if the protein supply is reduced much, the gains are apt to be lessened, and more feed required per 100 lbs. gain. Also, there will be a tendency for the cattle to sell at a lower price, because of less satisfactory finish.

1162. When is a protein supplement needed?—The protein content of the roughage will chiefly determine whether a protein supplement is required, and also the amount advisable, if one is needed. Legume hay, legume silage, legume pasture, and even young, actively-growing grass pasture are all so rich in protein that fattening cattle make good gains on plenty of such roughage with corn or other grain, without any protein supplement.

In rations for fattening cattle the kind of grain is also an important factor. A supplement may be needed when cattle are fattened on corn or other low-protein grain, while no supplement may be required if the grain is oats, wheat, or barley, which have more protein than corn. The example rations given in Appendix Table VII show when a protein supplement is needed for the various classes of beef cattle, and also the approximate amounts required to balance the ration.

If the roughage for fattening cattle is entirely non-legume, such as corn or sorghum silage, grass hay, or corn fodder, good results cannot be secured without a protein supplement. Also, a pro-

tein supplement is needed when beef breeding cows or young cattle are wintered on such roughage.

Several experiments have shown the importance of adding a protein supplement to a protein-poor ration for fattening cattle.[3] The addition of the supplement not only greatly increases the rate of gain, but it also reduces the amount of feed required per 100 lbs. gain and raises the selling price of the cattle. When care is taken to feed no more protein supplement than is actually needed to balance the ration, each 100 lbs. of such a supplement as linseed meal, soybean oil meal, or cottonseed meal will be equal in value to 250 to 300 lbs. of grain or grain equivalent. This value considers not only the saving in amount of feed per 100 lbs. gain, but also the higher selling price, because of better finish.

1163. Adding a protein supplement to grain and legume forage.—Whether it will pay to add a protein supplement to a ration of grain and legume forage for fattening cattle will depend on the amount of legume forage actually eaten, on the protein content, and on the age of the cattle.

Good alfalfa hay provides plenty of protein when 2-year-old cattle are full-fed corn grain and such hay. The same is true of soybean hay and cowpea hay, which have about as much protein as does alfalfa. For example, the addition of linseed meal or cottonseed meal to corn and alfalfa hay in Nebraska trials did not increase the gains of 2-year-old steers, raise the selling price, or reduce the feed required per 100 lbs. gain.[4]

Younger fattening cattle need somewhat more protein for maximum gains. Hence, the addition of a protein supplement to a ration of corn and a liberal amount of alfalfa hay will usually increase the gains of calves and yearlings a trifle. However, the saving in amount of feed required per 100 lbs. gain will not generally be enough to give the supplement a much higher value than corn per ton. For example, in 7 experiments calves fed only corn and alfalfa hay ate an average of 13.3 lbs. corn and 6.3 lbs. alfalfa hay a day and made the very satisfactory gain of 2.28 lbs. per head daily.[5] Others fed 1.1 lbs. a day of linseed meal or cottonseed meal in addition gained 2.38 lbs. On the average, however, each 100 lbs. of protein supplement saved only 73 lbs. corn and 60 lbs. hay. Under usual price conditions, it did not pay to feed the supplement.

When calves or yearlings full-fed on corn eat less than 4 to 6 lbs. a day of alfalfa hay, there will be more advantage from adding a protein supplement. Thus, in 3 Nebraska trials with yearlings, the addition of 1 lb. of cottonseed meal per head daily to a ration of 13.9 lbs. corn and 4.2 lbs. alfalfa hay increased the gain from 2.22 lbs. a day to 2.38 lbs.[6] Each 100 lbs. of cottonseed meal saved 131 lbs. corn and 40 lbs. of hay.

When cattle are full-fed corn with alfalfa hay as the roughage, the benefit from adding a protein supplement is greatest during the latter part of the fattening period, as they then eat less hay and more corn. Also, the protein supplement helps keep them on full-feed, when their appetites might otherwise lag.

When red clover or lespedeza hay is fed with corn to fattening cattle, there is more advantage in adding a protein supplement, because these hays are lower than alfalfa in protein. A ration of red clover hay and corn does not supply quite enough protein for the best results in fattening even 2-year-old cattle. For example, in 5 experiments 2-year-old steers fed an average ration of 18.7 lbs. shelled corn and 9.9 lbs. clover hay made the fairly satisfactory gain of 2.08 lbs. a day. Adding a protein supplement increased the gain to 2.38 lbs., on the average.[7]

When the grain fed with legume hay is barley, wheat, or oats, there is less need of adding a supplement than with corn, because of the higher protein content of these grains.[8]

1164. Supplement needed with part non-legume roughage.—When legume hay or legume silage forms only part of the roughage for fattening cattle, the amount of protein in the ration is

correspondingly decreased and the need of a supplement is greater. The amounts of supplement needed for various combinations of roughages and grain are indicated in the example rations given in Appendix Table VII. The exact amount required in any particular ration can readily be found by computing a ration which is balanced according to the feeding standards.

When fattening cattle are fed all the corn or sorghum silage they will eat in addition to hay and corn or other grain, the silage is so palatable that they will generally eat but 2 to 4 lbs. of hay a day, even when it is legume hay of good quality. This small amount of legume hay is insufficient to balance the ration fully, and therefore the gains will be increased considerably if a supplement is added.

A protein supplement is especially needed in such a ration for fattening calves, because of their higher protein requirements. For example, in 8 experiments the addition of 1.5 lbs. per head daily of linseed meal or cake to a ration of corn grain, corn silage, and alfalfa hay increased the daily gain from 2.01 lbs. to 2.29 lbs. and raised the selling price 42 cents per 100 lbs.[9] (In 6 of the trials the calves were fed a mixture of corn and oats while they were being started on feed.) In each of the tests the net return per head over feed costs was greater for the supplement-fed calves, the average net return being $2.75 more. In these experiments each 100 lbs. of linseed meal was worth as much as 230 lbs. of corn grain, considering all factors.

A PROTEIN SUPPLEMENT IS NEEDED WITH CORN SILAGE

When fattening cattle are fed corn or sorghum silage, a protein supplement is needed to balance the ration.

Similar results were secured in trials with fattening calves in which 0.9 lb. cottonseed meal per head daily was added to a ration of corn grain, sorghum silage, and alfalfa hay.[10] In these trials each 100 lbs. of cottonseed meal was worth as much as 287 lbs. of corn.

A ration of corn grain, corn silage, and alfalfa hay is more nearly balanced for older cattle. In 6 experiments the addition of 2.3 lbs. per head daily of protein supplement to this ration for fattening 2-year-old steers increased the daily gain from 2.22 lbs. to 2.34 lbs.[11] A greater amount of protein supplement was fed in these trials than later experiments have

shown to be necessary. Partly because of this, the use of the supplement was not profitable. It probably would have paid to feed 0.50 to 0.75 lb. of supplement per head daily.

With red clover or mixed hay in place of alfalfa hay, fed along with corn silage and corn grain, a protein supplement is needed even for 2-year-old cattle. Thus, in 14 trials the addition of cottonseed meal or linseed meal to a ration of shelled corn, red clover hay, and corn silage increased the daily gain of 2-year-old steers from 2.1 lbs. to 2.5 lbs.[12] Also, the selling price of the cattle was raised 33 cents per hundredweight and the net return over cost of feed was greater.

When a ration is deficient in protein, it is important to add sufficient protein supplement to balance it properly. This is well shown by 4 Oklahoma experiments in which fattening calves were full-fed ground corn and sorghum silage, with only 1 lb. of alfalfa hay per head daily.[13] Calves fed 1.5 lbs. of cottonseed cake gained 0.2 lb. more a day than others fed but 0.5 lb., yielded better-finished carcasses, and gave a 40 per cent higher net return.

1165. Quality of protein.—For the reasons explained in Chapter V, the quality or kind of protein is of nowhere near as great importance in feeding beef cattle as it is for swine or poultry. (**112**) When beef cattle are fed even a rather limited amount of legume roughage, the ration will usually provide protein of adequate quality. On the other hand, if the ration contains little or no legume roughage, and especially if the roughage is of poor quality, attention should be given to the quality of protein supplied by various protein supplements.

Experiments have shown, for example, that corn gluten meal is decidedly less efficient than such supplements as linseed meal, soybean oil meal, or cottonseed meal in balancing a ration of grain and non-legume roughage for fattening cattle. (**715**) In such rations this corn by-product should therefore be combined with supplements that provide protein of better quality.

Differing from the results with cattle full-fed on corn grain, corn gluten meal has been fully equal to linseed meal or soybean oil meal when 1 lb. of supplement per day has been added to sorghum silage for wintering beef calves or yearlings. This may indicate that although sorghum forage is low in protein, the quality of the protein is better than that of corn grain.

For beef cattle protein supplements of animal origin—meat scrap, tankage, or fish meal—do not have the special value which they have for swine and poultry. (**907, 922**) It has been shown in Chapter XXIII that these animal by-products can be used satisfactorily for cattle, if they furnish protein more cheaply than do the supplements commonly fed to cattle. However, they had best be mixed with better-liked supplements, for they are often not very palatable to cattle.

1166. Urea as a protein substitute.—Many experiments have been conducted during recent years to study the use of urea as a protein substitute for beef cattle.[14] The most extensive of these investigations are experiments by the Oklahoma Station with fattening calves and with calves, yearlings, 2-year-old steers, and mature cows being wintered.

As is stated in the general discussion in Chapter V concerning urea, it gives the most satisfactory results as a substitute for part of the protein when it replaces not more than about one-fourth of the protein in a ration, and when some grain is fed. (**129**) It is usually less effective as a protein substitute when it replaces more of the protein. It generally does not equal an ordinary protein supplement, such as soybean oil meal or cottonseed meal, when used as a substitute for all of the protein supplement, especially when fed without grain, but mixed with molasses or alfalfa meal.

In 6 Oklahoma experiments fattening calves were full-fed on ground corn and Atlas sorghum silage, with 1 lb. per head daily of alfalfa hay and 1 lb. of cottonseed meal or cake or else 1 lb. of pelleted mixed supplement in which urea replaced half of the cottonseed meal

or cake.[15] In these trials urea supplied about 13 per cent of the protein equivalent in the urea-pellets ration. On the average, the ration with the urea pellets produced just as rapid gains as did cottonseed meal or cake, and the selling price of the fat steers was as high.

In contrast with these excellent results with urea, the gains of fattening calves were unsatisfactory when pellets were used in which 85 per cent of the protein equivalent was supplied by urea. Also, pellets in which urea furnished half of the protein equivalent were inferior to cottonseed meal pellets as the supplement for heifer calves wintered on mature and weathered native pasture.

Florida experiments show that in a ration containing no grain, urea is not a perfect substitute for part of the protein supplement usually fed.[16] In 4 trials fattening steers fed hay, dried citrus pulp, molasses, and cottonseed meal gained an average of 2.28 lbs. a day and required 433 lbs. total digestible nutrients per 100 lbs. gain. When urea replaced 40 per cent of the cottonseed meal, the daily gain was 2.18 lbs., and 456 lbs. total digestible nutrients were needed per 100 lbs. gain.

1167. Mixed protein supplements.—Some protein supplements, especially soybean oil meal or peanut oil meal, give excellent results when used as the only protein supplement for fattening cattle or for cattle being carried through the winter. This is because they furnish protein of good quality.

On the other hand, it has been shown previously that corn gluten meal or cottonseed meal is generally of lower value than linseed meal, when either is used for fattening cattle as the only protein supplement to such a ration as corn grain, corn silage, and hay. (**715, 831**) However, a mixture of one-half cottonseed meal and one-half linseed meal is fully equal to linseed meal. (**832**)

Other combinations of protein supplements that have given excellent results for fattening cattle are [17]: (1) One-third each of cottonseed meal, corn gluten meal, and linseed meal; (2) one-third each of cottonseed meal, linseed meal, and either soybean oil meal or ground soybeans; (3) one-fourth each of cottonseed meal, linseed meal, corn gluten meal, and soybean oil meal or ground soybeans.

There is apparently more advantage in using such a mixture of protein supplements for fattening cattle which are full-fed on grain and which consequently eat relatively little roughage, than for cattle being wintered on roughage plus a small amount of protein supplement. Thus, in Nebraska trials with beef calves being wintered on prairie hay, there was no advantage in using a mixture of soybean oil meal, cottonseed meal, and linseed meal as the supplement, instead of the single supplements.[18] The results were similar in an Oklahoma trial with steers being wintered on native grass pasture.[19]

In metabolism experiments with steers at the Oklahoma Station the protein of a mixture of soybean oil meal, cottonseed meal, and peanut oil meal, used as the supplement to prairie hay, was not significantly better than the protein of the single supplements.[20]

Even with very poor late-cut grass hay as the only roughage for fattening cattle in Ohio trials, soybean oil meal gave as good results as a mixture of soybean oil meal and meat scrap.[21]

In later articles the use is discussed of complex mixed supplements containing not only a protein supplement, but also such ingredients as alfalfa meal, molasses, vitamin supplements, and minerals, including trace minerals. (**1178**) Some of these mixed supplements are much lower in percentage of protein than the common oil meals.

1168. Mineral requirements.—Beef cattle should always be supplied with salt regularly, except in the few areas where the forage or water contains an unusual amount. (**140**) Whether or not there will be any benefit from the use of a calcium or phosphorus supplement will depend entirely on the amounts of these minerals in the particular ration, as is shown later. The amounts of calcium and phosphorus advised per head daily for the various classes of beef cattle are

stated in the revised Morrison feeding standards. (Appendix Table III.)

Wherever there is trouble from goiter, or "big neck," in calves at birth, iodized salt should be supplied the breeding cows, at least during the latter part of the pregnancy period. (**170**) In areas where there is a deficiency of one or more of the trace minerals—cobalt, copper, or iron—the lack should be corrected by the use of a special mineral supplement, or by using trace-mineralized salt instead of common salt. (**172–181**)

There is no need of adding to the usual rations for beef cattle any other minerals, such as sulfur, potassium, or dirt.[22] Also, the addition of kelp to usual rations is not beneficial. (**977**)

1169. Salt.—Beef cattle should receive salt regularly, and the best method is to provide it where they can take what they wish, instead of salting them only once or twice a week.

The need by cattle for salt (sodium chloride) is commonly to furnish additional sodium.[23] Any ordinary ration apparently supplies enough chlorine.

Studies of the salt requirements for beef cattle have recently been conducted by the Kansas Station, with the aid of the Salt Producers Association.[24] These experiments show that cattle being wintered mostly on roughage are evidently benefited much more by supplying salt, than are fattening cattle full-fed on grain and eating much less roughage.

In 3 trials beef calves wintered on roughage and a small amount of protein supplement, with no salt supplied, gained an average of 40 lbs. per head less than did others receiving salt. The addition of salt slightly increased the digestibility of the ration and produced much cheaper gains. In contrast with these results, in 3 trials fattening calves full-fed grain and furnished no salt, gained about as rapidly as others supplied salt.

It is not advisable to mix salt with the concentrates for beef cattle, instead of allowing them to take as much as they desire. In an Arizona experiment fattening cattle allowed access to salt gained 2.58 lbs. per head daily, while others gained only 2.30 lbs. when a supposedly proper amount of salt was included in the concentrate mixture.[24a]

For feeding where the salt is not exposed to the weather, loose salt, block salt, and rock salt are all satisfactory. Loose salt is not desirable for feeding in the open, because of the great loss through weathering. Cattle prefer the softer kinds of block salt to that which is very hard, and they usually eat somewhat more salt when fed loose salt than when supplied with block salt.

In Iowa experiments over several years, cattle fattened in dry lot with shelter ate an average of about two-thirds pound of block salt per head per month.[25] Where salt is in the open, about twice this amount must be supplied, to allow for wastage. In these tests the results were equally good from feeding block salt and loose salt.

Cattle on pasture consume much more salt than those fed in dry lot, and they eat more in spring and early summer, when the forage is abundant and succulent, than later in the season. In a Kansas test yearling and 2-year-old steers on pasture consumed about 2.8 lbs. of block salt per head in July, 1.8 lbs. in August, and 1.2 lbs. in September and October.[26] Nearly equal amounts were lost by weathering of the salt blocks. In another Kansas test, when a salt mixture was fed which was advertised as repelling flies from cattle, no such effect was noted.[27]

Under range conditions a total of about 20 to 30 lbs. of salt is usually provided for each cow during the year.[28] The salt allowance should be from 2.0 to 2.5 lbs. per head a month, when the feed is succulent or when the cattle are subsisting largely on browse. Later in the season, 1.0 to 1.5 lbs. per month are usually sufficient.

1170. Self-feeding a mixture of protein supplement and salt.—In order to save labor, instead of feeding a protein supplement each day to beef cattle on range or pasture, a mixture of the protein supplement and salt is often self-fed. The proportion of salt is adjusted so the

cattle will eat the desired amount of protein supplement a day. (142)

As is pointed out in Chapter V, it is essential in this method that the cattle have access to plenty of water, conveniently available, so that they can get rid of the excess salt in the urine. Otherwise, there may be injury or even death loss. Beef cows have consumed a surprising amount of salt (over 2 lbs. per head daily) for long periods without injury, if they were able to get plenty of water.

Several studies have been made of this method.[29] Usually, the feed cost will be higher than when the proper amount of protein supplement is fed once a day, or when double the amount is fed every other day, and the gain in weight may not be quite so good. The saving in labor may fully offset these factors.

In beginning to use this method, at first the cattle should be hand-fed a mixture of 1 part of salt to 5 or 6 lbs. of protein supplement. Then the proportion of salt should be increased until they will eat no more than the desired amount of protein supplement. A larger proportion of salt is needed with older cattle than with calves. Usually about 1 part of salt to 3 parts of protein supplement will limit the daily consumption of the supplement to 2 lbs., and 1 part of salt to 2 lbs. of supplement will reduce the amount of supplement to 1 lb. a day.

Recent tests indicate that gypsum, instead of salt, may be mixed with the protein supplement, to control the amount eaten.

1171. Calcium.—When legume hay or other legume forage forms any considerable part of the roughage for beef cattle, there is no lack of calcium. Consequently, there is no benefit from adding a calcium supplement like ground limestone to such rations.[30]

If little or no legume roughage is fed, there is much more apt to be a deficiency of calcium for fattening cattle than for breeding cows or young stock which are being wintered chiefly on roughage. This is because all the grains are much lower in calcium than even non-legume hay, fodder, or silage. Fattening cattle which are fed liberally on grain consequently eat only limited amounts of roughage. They therefore get much less calcium than do cattle being wintered mostly on roughage.

Extensive experiments at the Kansas Station and also other trials have proved the importance of adding a calcium supplement to a fattening ration of grain, non-legume roughage, and protein supplement.[31] In these experiments fattening cattle made decidedly smaller and less economical gains on rations of grain, protein supplement, and either sorghum silage or sorghum silage and prairie hay for roughage, than they did when fed a limited amount of alfalfa hay. However, when 0.1 lb. ground limestone or similar calcium supplement was added to the non-legume ration, the gains were nearly as rapid as when alfalfa was fed. The cattle fed the calcium supplement also had stronger bones, required less feed for 100 lbs. gain, and yielded carcasses of higher slaughter grade.

The results of these experiments do not mean that prairie hay or other grass hay was equal to legume hay in value per ton. A much greater amount of protein supplement is, of course, needed to balance the ration when no legume hay is fed.

If fattening calves eat only about 2 lbs. or less of legume hay per head daily, along with a full feed of grain and corn or sorghum silage, plus a protein supplement, it is wise to add 0.05 to 0.10 lb. of calcium supplement to the ration.[32] Such a small amount of legume hay may not provide quite enough calcium for calves, since they need more calcium in their feed than do older cattle.

Whether there will be a benefit from feeding a calcium supplement to beef cows or young cattle that are wintered on non-legume roughage, will depend entirely on the calcium content of the roughage. Unless the forage has been grown on soil very deficient in calcium or unless it is of very poor quality, probably a calcium supplement is not needed.

If the supply of phosphorus in the feed is somewhat below the requirement, adding a calcium supplement when not required may be injurious, instead of

beneficial.[33] When one is in doubt as to whether to use a calcium supplement he should therefore consult his experiment station or county agent. It should be borne in mind that such a phosphorus supplement as bone meal furnishes twice as much calcium as phosphorus.

Limestone and bone meal ground so fine that they were floury gave no better results than coarser products in recent Nebraska and Tennessee studies.[34]

1172. **Phosphorus.**—It has been emphasized in Chapter VI that in many districts of this and other countries the soil and consequently the forage grown on it are so low in phosphorus that severe phosphorus deficiency occurs in cattle. (150–155) In all such areas, if the phosphorus deficiency is not corrected by applying phosphate fertilizer, it is very important to supply a mineral mixture furnishing phosphorus for cattle that are maintained entirely or chiefly on forage.

A decided lack of phosphorus produces the serious results described in Chapter VI. Also, Kansas experiments show that cattle fattened on a phosphorus-deficient ration yield beef which is inferior in palatability and keeping quality, and has a higher shrinkage.[35]

Fattening cattle are much less apt to have an insufficient supply of phosphorus than are beef breeding cattle or young growing cattle. This is because fattening cattle are generally fed a liberal amount of grain. The cereal grains have more phosphorus than most hay, or than corn or sorghum forage. Also, when grown on a soil low in phosphorus, the percentage of the mineral in grain will be fair, though the yield will be reduced. On the other hand, hay, pasturage, and other forage grown on phosphorus-poor soil may be seriously deficient in phosphorus. If a ration for fattening cattle contains, in addition to grain, 1 lb. or more per head daily of cottonseed meal, linseed meal, wheat bran, or other protein supplement that is rich in phosphorus, the ration will generally have enough phosphorus, unless the roughage is low in the mineral.

In most of the experiments with fattening cattle, there has been no benefit from adding a phosphorus supplement to such a ration as corn or other grain, fed with roughage grown on fertile soil, and with or without a protein supplement.[36] In cases where a phosphorus supplement has increased the gains, the improvement has been slight.

When feeds that are low in phosphorus form a considerable part of the ration for fattening cattle, there is apt to be a lack of the mineral. A phosphorus supplement should therefore be supplied when considerable beet pulp, beet molasses, or cane molasses is fed, or when the roughage comes from phosphorus-deficient land.[37]

Whether a phosphorus supplement should be supplied beef cows or young cattle on pasture or range, or being wintered on harvested feeds, will depend entirely on the phosphorus content of the forage. In areas where there is no deficiency of phosphorus in pasture or other forage, there is no benefit from a phosphorus supplement.[38] On the other hand, in phosphorus-deficient areas it is essential that a suitable phosphorus supplement be provided.

Experiments on the King Ranch in Texas show the importance of supplying phosphorus for range cattle in such areas as the Gulf Coast region of Texas, where there is a serious lack of phosphorus.[39] Cows given no phosphorus supplement averaged 200 lbs. lighter in weight than those receiving phosphorus. About half of them showed decided symptoms of phosphorus deficiency. Some became so stiff and "creepy" that they were unable to rise without assistance, and a few died as a result of the deficiency.

Cows supplied with bone meal or given soluble phosphate in the drinking water remained in good condition, a larger percentage had calves each year, and the calves were decidedly heavier and in better condition at weaning time. The results were still better where phosphate fertilizer was applied to the range pasture. Because of the much greater yield of grass, the carrying capacity of this pasture was increased 50 per cent. Also, the calves were heavier at weaning time than in the groups of cattle fed

a phosphorus supplement on unfertilized pasture.

In range areas, phosphorus deficiency is especially apt to occur when cattle must live during a considerable part of the year on mature, weathered grass and other forage, from which the phosphorus has been largely lost by weathering. (361) New Mexico experiments show that there may be a decided benefit from supplying a phosphorus supplement, even when the lack of phosphorus is not serious enough to produce marked symptoms of deficiency.[40] In these tests the percentage calf crop was increased considerably and the weaning weights of the calves were decidedly raised when the range cows were supplied a phosphorus supplement throughout the year, instead of merely during the season when the range forage was mature and dry.

Definite information concerning the minimum phosphorus requirements of the various classes of beef cattle is still very limited. In Idaho experiments it was found that rations for fattening cattle should have 0.18 per cent phosphorus to prevent any deficiency.[41] Such rations supplied about 20 grams (0.044 lb.) of phosphorus daily per 1,000 lbs. live weight. Phosphorus in grain or cottonseed meal was as effective as phosphorus in bone meal in meeting the needs of cattle. (151)

From Wyoming studies it was concluded that heifers raised under range conditions should receive at least 15 grams of phosphorus daily per 1,000 lbs. live weight.[42] An allowance of 17 grams of phosphorus per head daily was sufficient through the first gestation and lactation.

Texas studies indicated that range forage was deficient in phosphorus if it contained less than about 0.16 per cent on the air-dry basis.[43]

1173. Supplying a phosphorus supplement.—When a phosphorus supplement is needed by beef cattle, the best method of supplying it is generally to let them have free access to a suitable phosphorus-rich mineral mixture in a mineral box or trough. Mineral mixtures that are adapted to various conditions are described in Chapter VI. (**186**)

Information is also given in Chapter VI concerning the different phosphorus supplements. (**158–167**) A phosphorus supplement high in fluorine, such as rock phosphate or soft phosphate with colloidal clay (colloidal phosphate), is not safe for continued feeding. (**168–169**)

1174. Trace minerals.—Fortunately, for beef cattle in the greater part of the United States there is no lack of any of the trace minerals. Several experiments have shown that where there is no such deficiency, there is no benefit from supplying trace minerals by using trace-mineralized salt instead of common salt, or by including trace minerals in a mineral mixture.[44]

On the other hand, in an area where there is an actual deficiency of a trace mineral, especially cobalt or copper, the lack must be corrected, as explained in Chapter VI. (**172–175**) Otherwise, the results may be serious.

Also, there may be a benefit from supplying beef cattle with trace minerals if the only roughage they get is of very poor quality, such as late-cut, mature hay or else straw, or if such a feed as ground corn cobs is used instead of hay and silage.[45] It is therefore wise to supply trace minerals in such cases, even in areas where there are no trace mineral deficiencies when cattle have good roughage.

The need for a trace mineral supplement is therefore distinctly an area or an individual problem. Anyone in doubt as to whether there will be an advantage from using such a supplement should therefore secure *impartial* advice from his agricultural college, experiment station, or county agent.

1175. Vitamin requirements.—The only vitamin that is important for beef cattle under usual conditions is vitamin A. This is discussed in detail in the following article.

Even when beef cattle receive no feeds containing appreciable amounts of vitamin D, they are generally protected against any lack because they are commonly outdoors most of the daytime throughout the year. (**201**)

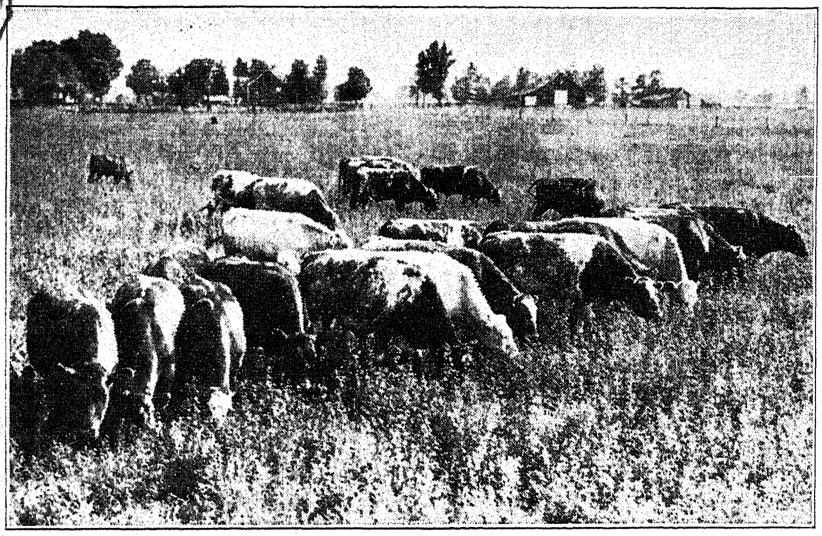
Vitamin D deficiency may occur if beef calves being fitted for show are kept in the stable during the day and are supplied with all the concentrate mixture they will eat, and in addition with all the milk they will take, by means of nurse cows.[46] They then consume but little hay. In such cases, it is advisable to include a vitamin D supplement in the concentrate mixture. (1118)

There is generally no deficiency of vitamin E in beef cattle kept under good practical conditions. However, "white muscle" disease, or muscular dystrophy, of beef calves is a serious problem in a few western range herds.[47] This disease is similar in symptoms to the fatal results of feeding calves a ration devoid of vitamin E. The muscular dystrophy, or degeneration, commonly affects the heart chiefly, and the calf dies suddenly. It differs in this respect from the "stiff lamb" disease, described in Chapter XXXI.

The trouble seems to be more apt to occur in herds where the cows have been wintered on roughage of very poor quality, and subsides when the cows are turned on good pasture. Although the trouble has not been prevented in some cases by a vitamin E supplement, it would seem wise to use the same methods of prevention that are effective in the case of the "stiff lamb" disease.

So far as is known, there is no lack of the other vitamins in feeding beef cattle. (208, 221)

1176. Carotene and vitamin A.—The vitamin A requirements of cattle are commonly expressed in terms of carotene, because cattle get the vitamin from this plant source under all usual conditions. (193) In their report on "Recommended Nutrient Allowances for Beef Cattle," a special committee of the National Research Council recommends an allowance of 5.5 milligrams of carotene daily per 100 lbs. live weight for growth and reproduction.[1] It is believed that approximately this amount is needed to build up and maintain a safe reserve of vitamin A in the body, and for successful reproduction, though considerably smaller amounts have permitted normal growth and reproduction of cattle in various



GOOD PASTURE SUPPLIES AN ABUNDANCE OF CAROTENE

Cattle on good pasture have such an abundant supply of carotene that they are able to store considerable vitamin A and carotene in their bodies. Legume pasture, such as this, is also very rich in protein and calcium.

experiments.[48] For cows nursing calves, a more liberal allowance is recommended, to ensure a satisfactory vitamin A content in the milk.

Beef cattle will receive plenty of carotene when they are on green pasture or when they are fed a reasonable amount of well-cured hay, corn or sorghum fodder, or silage.[49] On the other hand, they may suffer from severe deficiency, if they are maintained for a considerable part of the year on mature, weathered range forage, or if they are fed only such roughage as cottonseed hulls, straw, or hay or fodder of poor quality.

Fortunately, when cattle are on good pasture or are fed plenty of carotene-rich harvested roughage, they store considerable vitamin A and carotene in their bodies. This store is drawn upon, if the supply in the feed becomes inadequate. The length of time cattle can be fed a carotene-poor ration without showing symptoms of vitamin A deficiency will depend on their body store and their age. Calves suffer from a deficiency sooner than older cattle.

In Texas experiments when calves that had been on range pasture were fed a carotene-poor ration, some showed symptoms of vitamin A deficiency within 40 days.[50] The first symptom was usually night blindness, though sometimes convulsions occurred first.

Beef cattle should not be fed for a very long period on a ration that does not include sufficient good roughage to meet the carotene requirements. Vitamin A deficiency will usually be prevented if cattle are fed at least 2 lbs. per head daily of good-quality alfalfa or other legume hay, or 5 to 6 lbs. of corn or sweet sorghum silage, along with other roughage. Grain sorghum silage must be fed more liberally, as it generally has less carotene. On the other hand, hay crop silage is especially rich in carotene.

Although beef breeding cows are often wintered in the wheat-growing districts of the West on nothing but straw plus 1 lb. per head daily of protein supplement, such a ration cannot be advised except under emergency conditions. (**622, 1211**) There should also be supplied, if possible, a limited amount of well-cured hay or other roughage high in carotene or a vitamin A supplement, and also a calcium supplement.

Recent experiments show that beef cows which have been on good pasture during the growing season can usually be wintered on carotene-poor rations, without injury to the cows themselves. However, if they calve before they go on green pasture, the calves may suffer seriously from a deficiency of vitamin A, because the milk will have but little of the vitamin. A vitamin A lack is most serious for calves from birth to about 3 months of age.

When a deficiency of vitamin A occurs under range conditions, it is likely to be complicated with lacks of other nutrients. In North Dakota experiments beef cows that had previously been on good pasture had thrifty calves when the cows were fed for as long as 8 months a ration low in carotene, but supplying ample protein, minerals, and energy.[51]

In an Oklahoma experiment beef heifers were fed low carotene rations in dry lot for consecutive years.[52] They grew normally and successfully completed 2 gestation periods. However, their milk had too little vitamin A to protect the calves against deficiency. In the third gestation on the vitamin-poor ration, all of the cows aborted because of the lack of vitamin A and some died.

New Mexico and Florida studies show that beef cows wintered on mature range pasture will not be affected by a lack of vitamin A, so long as there is even a small amount of green feed in the pasture.[53] In case there has been severe drouth during the growing season and the cows consequently have little store of vitamin A, they may need a supplement furnishing the vitamin.

The disastrous results that follow when cattle are forced to live for a long time on mature and weathered grass or similar forage, are shown by California experiments.[54] Under such conditions cows may produce badly deformed calves. These are known locally as "acorn calves," because it was supposed that they resulted from the cows eating too

many acorns. The experiments showed, however, that acorn calves result when the cows are forced to live for too long a time on mature, weathered forage, with its multiple deficiencies.

If fattening cattle are fed for several months on all the grain they will eat, with but little roughage or with poor roughage, they may suffer from vitamin A deficiency unless the grain is yellow corn, which has some vitamin A value. The deficiency may produce generalized swelling, or edema, known as "anasarca."[55] In such cases, feeding good alfalfa hay has brought striking improvement within 1 to 3 weeks.

1177. Importance of good roughage for fattening cattle.—In most rations for cattle good roughage is the chief source of carotene and also of calcium and certain other essentials. It is therefore not surprising that young fattening cattle do not make good gains when they get no good roughage, unless a special supplement is fed that makes good the lacks.

In two Nebraska tests yearlings fed nothing but ground ear corn and cottonseed cake for only 65 days made decidedly less rapid gains than others fed alfalfa hay as roughage.[56] In an Illinois trial cattle fed for 112 days only a mixture of ground oats, wheat, and corn, with cottonseed meal as a protein supplement, gained but 1.63 lbs. per head daily, in comparison with 2.45 lbs. for others fed alfalfa hay in addition.[57]

If the only roughage for growing or fattening cattle is of very poor quality, it is essential for good gains that a special supplement be fed, which makes good the various nutritive deficiencies. Such supplements are discussed in the following article.

1178. Adding alfalfa; complex supplements.—It has been shown earlier in this chapter that in rations for fattening cattle certain combinations of protein supplements are superior to such a single supplement as cottonseed meal or corn gluten meal. (1167) Also, it has been explained in Chapter II that for satisfactory digestion by ruminants of poor roughage, such as ground corn cobs, straw, cottonseed hulls, or even very poor late-cut hay, special supplements must be supplied. (45) The ration must not only be supplemented with protein or another source of nitrogen, but also with minerals, including perhaps trace minerals, and with certain other factors needed by the rumen bacteria.

The addition to the ration of a small amount of high-quality roughage, such as good alfalfa hay or alfalfa meal, will generally increase the gains considerably.

For example, in recent Ohio experiments steers full-fed on corn-and-cob meal, with late-cut, poor-quality timothy hay and a mineral mixture, gained 2.00 lbs. a day when the ration was supplemented with a mixture of soybean oil meal and dehydrated alfalfa.[58] With soybean oil meal as the supplement, others gained only 1.78 lbs. Because the cost of the dehydrated alfalfa was as great as that of the soybean oil meal per ton, the gains were more expensive with the dehydrated alfalfa. In all probability a similar increase in rate of gain could have been obtained by adding a little high-quality alfalfa or other legume hay to the ration.

It is shown in the following chapter that even with corn or sorghum silage as the only roughage for fattening cattle, the gain is usually increased by adding to the ration a little alfalfa hay or dehydrated alfalfa. (1232)

There has been much interest during the past few years in Purdue Supplement A, developed by Beeson and associates at the Indiana Station.[59] This supplement was designed especially for use with low grade roughages, such as ground corn cobs, but also gives excellent results with corn or other silage. (692)

The revised Purdue Supplement A contains, per 1,000 lbs.: Soybean oil meal, 650.5 lbs.; cane molasses, 140 lbs.; high-grade dehydrated alfalfa meal, 140 lbs.; bone meal, 52 lbs.; cobaltized salt, 17.0 lbs.; and vitamin A and D concentrate, 0.5 lb. In a previous formula molasses feed, containing molasses and a low-grade absorbent, was used instead of the dehydrated alfalfa and molasses.

Feeding 3.5 lbs. per head daily of Purdue Supplement A has been generally recommended. This supplies about 2.5 lbs. of soybean oil meal. While this amount of protein supplement may be needed by fattening cattle fed ground cobs for roughage, it is more than is necessary with corn or sorghum silage as the roughage. Also, with good roughage there is no need of a vitamin supplement.

Several experiments have been conducted to compare Purdue Supplement A or similar complex supplements with soybean oil meal or other simple supplements, in rations for fattening cattle fed roughage of ordinary good quality.[60] In most of the experiments the complex supplements, fed with such roughage, have produced no better gains than the simpler supplements, and the feed cost per 100 lbs. gain has been higher.

Various other complex supplements have been recommended for fattening cattle. For example, the "all-purpose" supplement was very satisfactory for beef cattle and also for other stock in Ohio trials. This supplement is a mixture of 30 lbs. meat scrap, 30 lbs. soybean oil meal, 20 lbs. cottonseed meal, 15 lbs. linseed meal, and 5 lbs. minerals (equal parts by weight of steamed bone meal, ground limestone, and salt.)[61]

A supplement for fattening cattle recommended by Burroughs of the Iowa Station has the following formula per ton: Soybean oil meal, 830 lbs.; cane molasses, 450 lbs.; dehydrated alfalfa, 450 lbs.; urea feed, 100 lbs.; dicalcium phosphate, 60 lbs.; stilbestrol premix, 10 lbs.; and dried torula yeast, 100 lbs.[62]

Whether it is advisable to use a complex supplement for beef cattle instead of an ordinary protein supplement, should depend on the quality of the roughage, and on the cost per ton of the supplement in comparison with such a supplement as soybean oil meal, linseed meal, or cottonseed meal.

1179. Percentage of protein in supplements; feeding every other day.—Many of the formula beef cattle supplements, or commercial mixed supplements, have much less protein than there is in soybean oil meal, cottonseed meal, or linseed meal. In addition to the common high-protein feeds, these contain feeds lower in protein, especially grain, molasses, and alfalfa meal. Some also have mineral and vitamin supplements.

The question therefore arises as to whether such a supplement, having 30 to 20 per cent protein or less, will be as economical as a supplement which has 40 per cent protein or more. The answer will depend, first of all, on whether the deficiency in the feed the cattle get is primarily a lack of protein, or whether they need additional energy about as much as they need more protein. Also, as has been pointed out previously, if they already have plenty of vitamins, a vitamin supplement is not beneficial.

The lower protein supplements may cost less per ton than an oil meal having 40 per cent protein or more, but the cost per pound of protein is much greater. If the lower protein supplement is made of only high-grade feeds, it may furnish about as much net energy per pound as an oil meal.

For wintering young beef cattle or beef cows, 1 lb. of a high-protein supplement, such as soybean oil meal, generally supplies enough protein to produce good results, when the cattle are fed good grass hay or corn or sorghum silage. Since the lack in such roughage is primarily a deficiency of protein, it will take correspondingly more of a supplement having only 20 to 30 per cent protein, to produce equal results.

To supplement mature and weathered native range pasture for young cattle, additional energy may be needed, as well as more protein. It may therefore be profitable to supply more than 1 lb. per head daily of supplement.

The Oklahoma Station has carried on several experiments to compare supplements having 40, 30, and 20 per cent of protein as the supplement to prairie hay or to native range, for wintering heifer calves and bred yearling heifers.[63] All supplements were fed in pelleted form.

The 40 per cent protein pellets were pelleted cottonseed meal. The

lower protein pellets were made of mixtures of cottonseed meal and ground corn. In addition, the lower protein pellets fed certain lots of the bred heifers also contained mineral and vitamin supplements. All the cattle had access to a mineral mixture of 2 parts salt and 1 part bone meal.

Calves fed 1 lb. per head daily of the 40 per cent protein pellets with prairie hay gained much more in winter than did those fed the lower protein pellets, but considerable of the difference was made up by their smaller gains on range pasture the following summer. At the end of the pasture season, their total gain averaged 40 lbs. more than for those fed the 20 per cent protein pellets in winter, and 17 lbs. more than for those fed the 30 per cent protein pellets.

The difference in results from the 40 per cent and the 20 per cent protein pellets was much less for the calves fed 1 or 2 lbs. a day of pellets as the supplement to winter range. Here there was a lack not only of protein, but also of energy.

Similar results were secured with the bred heifers fed 2.5 lbs. of 40 per cent or 20 per cent protein pellets as the supplement to winter range. At the end of the following summer, the weaning weights of the calves from the heifers fed the 40 per cent protein pellets in winter averaged only 7 lbs. more than of the calves from the heifers fed the 20 per cent protein pellets in winter, and the cost of winter feed was $2.16 higher.

There was only a very slight benefit from including mineral and vitamin supplements in the pellets for the bred heifers, and this was offset by the greater cost.

In order to save labor, sometimes beef cattle wintered on the range are fed a double amount of protein supplement every other day, instead of feeding the supplement each day. This does not seem advisable unless there is a great shortage of labor. It would seem that the method would be preferable of restricting the amount of protein supplement by self-feeding a suitable mixture of protein supplement and salt. (**1170**)

In 2 Kansas experiments yearling steers wintered on the range and fed a double amount of protein supplement every other day gained only about half as much as did others fed the protein supplement each day.[64] The effect of delayed feeding of a protein supplement has been discussed in Chapter V. (**116**)

1180. Addition of fat.—It has been mentioned in Chapter XXIII that recently there has been a surplus in this country of low-grade animal fats, largely because of the wide use of detergents instead of soaps. Because of this, the price of such tallows and greases has fallen so much that a small percentage has been added to some formula feeds, or commercial mixed feeds. (**914**) These low-grade animal fats usually sell at a much lower price than plant oils, such as corn oil or cottonseed oil.

In Texas trials adding 5 per cent of cottonseed oil to ordinary fattening rations did not increase the gain, but did reduce the amount of feed required per 100 lbs. gain.[65] Each pound of added fat saved 4 lbs. of other feed.

Adding 5 per cent of raw ground beef tallow to a fattening ration increased the rate of gain in Florida experiments, and increased the feed efficiency.[66] When 10 per cent of the tallow was added to the ration, the gain was reduced.

In Nebraska trials an ordinary ration of ground corn, soybean oil meal, and hay was compared with one in which corn-and-cob meal and hay were fed with pellets made of a mixture of 5.5 per cent beef tallow or corn oil and 68 per cent ground corn cobs, together with cane molasses, soybean oil meal, urea, and bone meal.[67] The ordinary ration produced slightly more rapid gains. With the tallow at 9 cents per pound and ground corn cobs at $16 a ton, in comparison with ground corn at $60 a ton, the gain was slightly cheaper with the pellets.

Animal fat added to a ration should be stabilized with an antioxidant. (**914**)

1181. Water.—It is important that beef cattle have an abundant supply of good water at all times. During winter in the northern states, water in tanks or

troughs should be kept from freezing by using suitable heaters, but there is no need otherwise of warming the water.[68] Separate water troughs should be provided for pigs running with the steers. While it is best to have water before beef cattle at all times, they readily adapt themselves to taking a fill once daily.

The water provision should be not less than 10 gallons per head daily for 2-year-old steers or breeding cows. In Ohio tests fattening calves drank 6.5 to 8.0 gallons of water per head daily.[69] The average daily water consumption of range cows in Arizona was 6.3 gallons, with a minimum of 2.6 gallons in winter and a maximum of 11.5 gallons in summer.[70]

1182. Antibiotic feed supplements; surfactants; tranquilizers; Tapazole.—Numerous experiments have been conducted during the past few years to determine the effect of adding an antibiotic feed supplement to the rations for beef cattle, especially fattening cattle.[71] Unfortunately, the results with the addition of various antibiotics, has varied considerably. This variation is not surprising when one considers the difference in rations, feedlot conditions, and disease levels which confounded the tests. In most of the carefully conduced experiments under good management conditions, little or no response has usually been secured. Indeed, in certain trials the addition actually has been detrimental. In Illinois, Kentucky, and Oklahoma experiments the digestibility of a ration for steers was reduced by adding an antibiotic.

The general acceptance of antibiotics in many large commercial feedlots supports the viewpoint that under such conditions, their use often increases performance. Levels which are commonly recommended for reduction of disease, less scouring, and improved feed efficiency and gain are approximately 10 milligrams per 100 pounds liveweight, with most commercial rations mixed for this purpose furnishing average feeder cattle from 50 to 100 milligrams per head per day of either aureomycin or terramycin. Less than 50 milligrams per head daily is not recommended.

Feeding such antibiotics has also reduced the incidence of bloat, liver abscesses, and foot rot under practical feedlot conditions. It should be stressed however, that antibiotics may not promote any response under many conditions of good management.

The use of high levels of either aureomycin or terramycin for a short period of time in feeder calf rations upon receipt in the yard may reduce the incidence and losses from the shipping fever complex.

Little information is yet available concerning the effect of adding surfactants to beef cattle rations. In a Maryland trial, such an addition was not beneficial with fattening steers. A new "chemobiotic," (tetra alkylammonium stearate) has given variable results. In work at Purdue and Iowa no response was secured, while at Montana and Washington, increases in both gain and feed efficiency were noted. Likely, the differences can be explained by the characteristics of the rations employed.

Tranquilizers, compounds capable of producing increased gain without sedation are now currently being tested. Many different types are under evaluation, and hydroxyzine (Tran-Q) has been approved for use in animal feeds at a level of 2.5 milligrams per head per day. In certain trials, the use of this compound in conjunction with stilbestrol has increased both gains and feed efficiency. The effect was apparently additive to that secured with stilbestrol and antibiotics.

Injectable tranquilizers may be used to quiet cattle at time of shipment to reduce shrinkage, and lessen losses from shipping fever, under the direction of a qualified veterinarian.

Tapazole (1-methyl, 2-mercaptoimidazole), a new compound not yet thoroughly tested or approved for use by the Food and Drug Administration, is reported as stimulating gains, improving feed efficiency, and increasing carcass quality. The levels used varied from 300 to 600 mg. per head daily. Apparently gains are stimulated only for a short period, with the effect tending to wear off.

1183. Stilbestrol; other hormones.—Although earlier results with implanting or injecting stilbestrol (diethylstilbestrol) or other sex hormones gave poor results,[74] present research shows little difference between oral administration of 10 mg. daily per head or implanting diethylstilbestrol at a level of 24 to 36 mg. per head once.

Early tests were often conducted using high levels which resulted in undesirable side effects, although promoting daily gain. Such side effects: elevated tail head, sagging of the loin, mounting of other cattle, mammary development, and sometimes in the case of heifers, prolapse of the vagina. Frequently, the grade of the carcass was lowered.

Many hundreds of trials [76, 77] have been conducted since Iowa [75] reported that 10 mg. daily of stilbestrol per head in the feed would promote increased gains and feed efficiency with little or none of the undesirable side effects previously produced by implantation.

A combination of estrogens, estradiol and progesterone (Synovex) administered at the recommended levels by injection apparently gives the same results as oral or implanted stilbestrol.

Varying effects secured by the administration of hormones are often explained by the fact that certain roughages contain small amounts of estrogenic-like compounds, lessening the response secured, and occasionally leading to undesirable side effects.

Recent Iowa tests indicate a certain calorie-protein ratio is optimum for best carcass quality with steers receiving stilbestrol. Also, increasing the oral dosage during the last 56 days of the feeding period (146 days) increased gains as compared to feeding 10 mg. thruout.

Combinations of silbestrol and testosterone implants were superior, especially with heifers, to stilbestrol alone in Colorado and Ohio trials.

The distribution of stilbestrol containing "premixes" is limited to manufacturers holding effective permits from the Federal Food and Drug Administration. (**964**)

In an Indiana experiment the feeding of a thyroprotein supplement to fattening heifers decreased the gain and the feed efficiency, and in an Oklahoma trial the addition of thyroprotein to a ration for beef cows nursing calves was not advantageous.[78]

1184. Amount of concentrates for fattening cattle.—One of the most important problems in beef production is deciding how much grain or other concentrates to use in fattening cattle for market. The financial outcome depends largely on a wise decision concerning this problem.

Many experiments have been conducted to determine the most profitable amounts of grain to feed fattening cattle of the various ages and under different conditions. These experiments have shown that when full use is made of high-quality roughage, including improved pasture, cattle can be fattened sufficiently to yield desirable carcasses with much less grain than was formerly believed necessary.

The various methods of beef production are discussed in some detail in the following chapter. It is there emphasized that local conditions will determine what method will be most profitable. In baby beef production calves of high quality are full-fed grain in dry lot after weaning and are marketed when thoroughly fat at 18 months of age or less. The calves may be farm raised or may be purchased from the western range. In the former case, the calves are often fed grain in a creep previous to weaning. Baby beef production requires a maximum amount of grain and other concentrates and does not utilize a large amount of pasture and harvested roughage.

At the other extreme is the method in which calves are wintered chiefly or entirely on roughage, pastured the following season without grain feeding, wintered on roughage again, and pastured without grain the second summer. At the close of the pasture season the cattle, then over 2 years of age, are generally fed a liberal amount of grain for 2 to 3 months, to get them fat enough to sell well. If the market does not pay a sufficient premium for grain-fed cattle, they

may be marketed direct from pasture, without receiving any grain. In this method maximum use is made of pasture, hay, and silage, and only a minimum amount of grain is needed.

1185. Fattening cattle on a minimum amount of grain.—In early years corn and other grains were usually so cheap that fattening cattle were generally fed all the grain they would eat, after they were safely on full feed. Two-year-old steers fattened in dry lot were fed an average of over 20 lbs. corn per head daily in addition to hay and other dry roughage.

Later, when corn silage came into wide use for fattening cattle, it was found that when cattle are fed all the well-eared corn silage they will clean up, they will not eat so much corn grain in addition to the roughage. The table in a later article shows the amount of grain and other feeds eaten by cattle of various ages when full-fed grain, along with corn silage, good hay, and a protein supplement. (**1195**)

As the price of corn and other grain became higher in comparison with the cost of hay and silage, several experiments were conducted to find whether 2-year-olds or yearlings can be made fat enough for the large markets when fed only corn or sorghum silage, hay, and 2 or 3 lbs. a day of protein supplement. The following table presents the results of 16 such tests, in each of which one lo of 2-year-old steers, averaging 979 lb in weight, was fed for an average of 1 days only well-eared corn silage, leg or mixed hay, and a limited amount of protein supplement, while another lot received a full feed of corn grain in addition.[79]

CATTLE ON A FULL FEED OF GRAIN

In the corn belt it is usually most profitable to feed fattening cattle a liberal amount of corn or other grain.

The steers fed no corn grain except that in the well-eared corn silage made the surprisingly good average daily gain of 2.1 lbs. per head. Before the introduction of the silo and the use of modern, well-balanced rations this would have been considered a good rate of gain on a liberal feed of grain. However, the steers full-fed corn made considerably more rapid gains, averaging 2.6 lbs. a day. As a result, they were much better

finished at the end of the fattening periods than the steers fed no corn grain except that in the silage.

Feeding no grain except that in corn silage

	Lot I No corn except in silage	Lot II Full-fed corn grain
Average ration		
Corn grain, lbs.	...	14.1
Supplement, lbs.	2.9	2.8
Hay, lbs.	3.8	2.9
Corn silage, lbs.	49.2	27.6
Average daily gain, lbs.	2.1	2.6
Feed per 100 lbs. gain		
Corn grain, lbs.	...	542
Supplement, lbs.	142	110
Hay, lbs.	199	117
Corn silage, lbs.	2,427	1,091
Feed cost per 100 lbs. gain	$14.25	$16.18
Selling price per 100 lbs.	$10.47	$11.17
Net return per head	$—0.03	$2.55

Some of these tests were carried on when corn was high in price, while others were conducted when corn was cheap. The feed costs per 100 lbs. gain accordingly varied widely in the individual trials. The cost with local prices for feeds at any time can readily be estimated from the data in the table. On the average, the feed cost per 100 lbs. gain in these trials was $1.93 higher for the steers full-fed on corn.

Other factors are fully as important as the cost of the gains in deciding the financial outcome. Much more pork is produced by pigs following full-fed steers than when no shelled corn is fed the cattle. Furthermore, full-fed steers reach a better finish and hence bring a higher price on the market. There was not, however, as much difference in the actual selling price in these trials as many experienced cattlemen would predict. In fact, the "no-corn" steers brought only 70 cents less per hundredweight than the others.

Because of the higher selling price and the greater pork credit, the full-fed steers made a much better net return than those fed no corn except that in the silage. However, in some of the experiments conducted when corn was extremely high in price, the cost of gains was so much lower for the no-corn cattle that they returned the greater profit. In other similar experiments with yearling or 2-year-old cattle, the results have generally been like those here summarized.[80]

Experiments have shown that unless grain is extremely high in price in comparison with roughages, it is practically always more profitable to give calves a liberal amount of grain during the entire fattening period.[81]

It has been shown in Chapter XV that when hay-crop silage is fed in place of corn silage, or when cattle are fed hay as the only roughage, considerable grain must be fed to produce as good gains and finish as are secured on corn silage, without additional grain. (439) This is because hay-crop silage and hay have less net energy, on the dry basis, than well-eared corn silage with its considerable proportion of corn grain.

In the alfalfa districts of the West where alfalfa hay is often very cheap in comparison with grain, and less premium may be paid for well-fattened cattle, it may be profitable to feed yearlings and 2-year-olds chiefly alfalfa hay, with but little grain. (1187)

1186. Feeding limited amounts of concentrates.—In fattening 2-year-olds or yearlings it may often be most economical to follow a middle course between full-feeding of grain and supplying no grain except that in the silage. One method is to feed only a limited amount of grain during the entire fattening period. Another method is to feed only roughage and a protein supplement for a time, and then add a liberal amount of grain during a finishing period of 40 to 60 days.

Experiments have shown that the latter method is usually preferable.[82] It generally takes less grain than when a half allowance of grain is fed throughout the entire fattening period. Yet, it produces fully as large gains and as good finish.

The results from giving 2-year-old steers a half feed of corn throughout the

fattening period, in comparison with full-feeding corn, are shown by 11 experiments.[83] Cattle full-fed corn for 131 days ate an average of 13.8 lbs. corn, 28.5 lbs. corn silage, 2.4 lbs. hay, and 2.6 lbs. protein supplement, and gained 2.7 lbs. per head daily. Others fed a half allowance of corn gained 2.3 lbs. on a ration of 6.9 lbs. corn, 41.0 lbs. silage, 2.7 lbs. hay, and 2.5 lbs. supplement.

The feed cost of 100 lbs. gain was 67 cents less for the steers getting the half feed of corn and they sold for only 44 cents less per hundredweight. However, the difference in selling price and the difference in the amount of pork produced by the pigs following the steers more than offset the cheaper gains, and the full-fed steers returned $3.35 more profit per head on the average.

Whether or not to limit the amount of grain for cattle being fattened in dry lot should depend on several factors. These include: the relative cost of grain and roughage and the amounts of each that are available; the grade or quality of the cattle that are to be fattened; the size of the premium that can probably be secured for well-fattened cattle; and how soon one wishes to have the cattle ready for market. Farmers who plan to fatten cattle mostly on roughage usually buy the plainer type of feeder cattle and those in rather thin condition. They know that they cannot hope to top the market with cattle fed largely on roughage, even if they are of high quality. They therefore buy cheaper cattle and feed them so as to secure low-cost gains.

Several experiments have been conducted recently by western experiment stations to determine the best proportion, or ratio, of concentrates and alfalfa hay or other roughage to feed fattening yearlings or 2-year-olds.[84] These trials show that the most rapid gains are generally secured when 2 or 3 lbs. of concentrates are fed to each pound of hay. Restricting the amount of roughage and thus increasing the proportion of grain and other concentrates beyond this level, tends to decrease the gain instead of increasing it. Still more important, such a high proportion of concentrates considerably increases the cost per 100 lbs. gain.

Feeding a smaller proportion of concentrates than 2 lbs. per pound of hay, reduces the gain and the cattle do not reach a good degree of finish. If it is desired to reduce the amount of grain fed, it is best to feed but little grain during the first month of the fattening period and then gradually increase it until the cattle get a liberal amount.

1187. Fattening cattle on alfalfa hay. Some years ago, cattle in certain of the western range districts were often fattened on only alfalfa hay, or on alfalfa hay and other roughage. Though young cattle cannot be made really fat on roughage alone, this method was economical because the local markets did not pay much premium for well-fattened cattle.

During recent years, few cattle have been fattened on alfalfa hay alone, because there has been a greater demand for beef from grain-fed cattle. However, in the western range areas, fattening cattle are even now often fed a considerably smaller amount of grain than are cattle fattened in the corn belt and eastward. This is because alfalfa hay is commonly cheap in comparison with the price of grain. In Arizona and New Mexico trials it was more profitable to feed yearling steers 7 or 8 lbs. of grain per head daily, along with good roughage, than to reduce the allowance to only about 4 lbs.[85]

In 16 tests some years ago, cattle fattened on alfalfa hay alone for periods averaging 110 days were fed 32 lbs. of hay per head daily (including the wastage) and gained only 1.20 lbs. daily.[86] For each 100 lbs. of gain there were required 2,985 lbs. of hay. In 8 of the experiments, adding a limited amount of grain to alfalfa hay increased the average gain 0.45 lb. a day. Each 100 lbs. of grain saved 308 lbs. of hay, without considering the better finish of the grain-fed cattle.

When cattle are fattened on alfalfa hay alone, poor-quality hay should not be chopped or ground in an attempt to reduce the wastage. This will force the cattle to eat the stems or weeds that they could otherwise discard, and is therefore apt to reduce the gains and be a disadvantage, instead of a benefit. The refuse hay can often be used advantageously for breeding cows or stocker cattle that are being wintered. Idaho and Oregon tests show that chopping good-quality alfalfa hay increases its value about

18 per cent for cattle being fattened on hay alone.[87]

Adding corn silage or other silage to alfalfa hay increases the rate of gain fully as much as feeding a limited amount of grain, and often the gains are cheaper than with grain. In 9 trials cattle fed silage and alfalfa hay gained 1.64 lbs. per head daily, while others fed nothing but alfalfa hay gained only 1.12 lbs.[88] Each 100 lbs. of silage actually saved an average of 115 lbs. of alfalfa hay in these tests, and in addition the silage-fed cattle were much better finished.

[illegible]. General Factors Influencing Beef Production

1188. The necessary margin.—Under usual conditions the cost per 100 lbs. of the gains made by feeder cattle fattened for market is greater than the selling price of the finished animals per hundredweight. Therefore, in order to make a profit or even to prevent loss, a higher price per 100 lbs. must be obtained for the fat cattle when marketed than their original cost per 100 lbs. as feeders. This is also generally the case in fattening feeder lambs or older sheep.

The difference between the cost per hundredweight of the feeder animals and their selling price per hundredweight when fattened is called the *margin.* The term *necessary margin* means the margin that is required for any particular lot of animals to avoid loss.

To find the margin that will be needed, the other expenses must be taken into consideration, in addition to the cost of feed for each 100 lbs. of gain. Where full value can be secured from the manure, this and the credit for the pork produced are commonly assumed to cover the cost of labor, housing, taxes, interest, incidental expenses, and the mortality risk. However, one must include in his financial estimates the expenses incident to the purchase of feeder cattle and of bringing them to the feed lot, and also the expenses of marketing them after they are fattened.

The following factors have an influence on the margin that is needed for any particular lot of cattle:

1. The higher the cost of the gains, the greater will be the necessary margin.

2. The more the animal weighs when placed on feed, the less is the necessary margin, because the increased selling price is secured on more pounds of initial weight. This factor will be offset, however, if the heavier cattle are older and make more expensive gains.

3. The higher the initial cost is of the feeder cattle per hundredweight, the smaller is the necessary margin. This is because the initial cost of the animals per 100 lbs. will then more nearly equal the cost of the gain per 100 lbs.

4. The larger the total amount of gain made per head by the cattle, the greater will be the margin needed to prevent loss. This is because the margin on the initial weight of the animal must cover a greater number of pounds of expensive gains.

5. A greater margin is needed when the expenses are heavy for getting the steers to the feed lot and later to the market.

In general, the necessary margin is usually less for fattening calves than for older cattle. This is because they make much cheaper gains, and also because their initial cost per 100 lbs. is commonly higher than for yearlings or 2-year-olds.

The manner in which the necessary margin can be estimated is shown by the following example: Let us suppose that 700-lb. yearling steers cost $22.00 per hundredweight when put in the feed lot. They are to be fed 160 days, and it is expected that they will gain 2.0 lbs. per head daily at a feed cost of $26.00 per 100 lbs. gain. Assuming that the pork produced by pigs following the steers and the value of the manure will offset the labor and miscellaneous expenses, what will be the necessary selling price and the necessary margin, after deducting the marketing expenses?

The steers will make a total gain per head of 320 lbs., and the total feed cost of this gain will be $83.20 at $26.00 for each 100 lbs. gain. Adding this to the total initial cost of the cattle per head, which was $154.00, we will have $237.20 as the total cost per head of the fat cattle. Dividing this total by the final weight of the cattle, which is 1,020 lbs. (700 lbs. plus 320 lbs.), we find that the cattle must bring $23.26 per hundredweight in the feed lot to break even.

To determine the necessary margin, we subtract the initial cost per hundredweight from this necessary selling price. This gives us $1.26 as the necessary margin under these particular conditions.

1189. Value of beef blood for beef production.—Experiments have proved

that "blood tells" in beef production, just as it does in other types of stock farming. Good returns cannot be expected when calves are raised for beef out of scrub or inferior cows, and sired by a scrub bull or one lacking in the desired beef characteristics.

In a survey by the United States Department of Agriculture among farmers in 36 states, it was estimated that purebred beef cattle had an earning power 37 per cent greater than that of common or scrub stock, based on utility alone and not considering the greater pride and pleasure in caring for well-bred cattle.[89] Those who had replaced scrub bulls with purebred sires reported an average increase of 48 per cent in returns due to the use of the purebred sires.

In comparison with scrubs, well-bred beef cattle have the following advantages: (1) They make more rapid gains and are therefore heavier at a given age; (2) the gains are usually cheaper; (3) the animals mature earlier; (4) they furnish a higher percentage of dressed carcass; (5) they produce a greater proportion of the more valuable cuts of meat; (6) their carcasses have less internal fat; and (7) their beef is superior in quality.

Several experiments have shown that well-bred beef cattle make more rapid and cheaper gains than scrubs. In 6 Oklahoma tests, for example, well-bred beef calves from a purebred sire and high-grade beef cows gained 1.97 lbs. a day in comparison with 1.67 lbs. for scrub calves and 1.88 lbs. for calves from purebred bulls and scrub dams.[90] Also, the feed cost per 100 lbs. gain was 10 per cent less for the well-bred calves than for the scrubs, and 4 per cent less than for the calves out of purebred bulls and scrub dams. In considering these results, it should be borne in mind that the scrub cattle were vigorous, thrifty animals and that they were fed and cared for as well as the well-bred beef cattle. Commonly, on farms where scrub animals are raised, the methods of feeding and management are no more improved than are the stock.

In all of the tests comparing well-bred beef calves with scrubs, the chief difference has been in the value of the cattle when marketed. Thus, in the Oklahoma trials the well-bred steers sold for $1.71 more per 100 lbs. than the scrubs, and for 92 cents more than the steers from purebred bulls and scrub cows.

1190. Superior carcasses of well-bred beef cattle.—Well-fattened steers of good beef type have a somewhat higher dressing percentage than scrub or dairy steers that are equally fat. Also, the beef steers have a higher percentage of loins and ribs, which are the most valuable cuts, and a smaller proportion of the cheap cuts. The actual differences in dressing percentage and in percentage of different cuts is not large, however.

There is a more marked difference in the distribution of fat in the body. In the carcass of a well-bred beef steer more of the fat is distributed throughout the muscular tissues, and less is deposited about the internal organs, where its only value is for tallow. Fat distributed throughout the lean meat makes it tender, juicy, and toothsome. On the other hand, when it is deposited in separate masses anywhere about the body, it has but low value.

One of the most important differences between beef cattle and scrub or dairy-bred cattle is in the quality of beef produced. The thick-fleshed cuts from well-fattened beef cattle command a much higher price on discriminating markets than the thin-fleshed cuts from scrubs or dairy animals. Fat cattle of good beef type therefore sell for a considerably higher price on the market and bring a much larger return to the man who has raised them.

1191. Fattening cattle of the various market grades.—For the beef producer who raises the animals he fattens, there is no question but what well-bred animals of the beef breeds are the most profitable. The matter is more complicated for one who fattens feeder cattle that he buys on the market. He must consider not only the cost of the gains he can expect from cattle of the various grade, but also the difference between the initial cost per hundredweight and

the probable selling price when fattened.

Careful experiments have shown that thrifty, well-selected common-grade or medium-grade feeder cattle will make fully as rapid and cheap gains as will good to choice feeders, which are of better beef type and conformation. This is chiefly because the lower grade feeders are generally thinner in flesh than the better cattle. Furthermore, when the cattle are marketed after being fattened, there will usually be considerably less difference in the selling price per hundredweight than there was in their cost as feeders. Consequently, the profit has generally been greater from the medium or common grades than from the better grades.

The results from fattening western feeder steers of various grades are shown by 15 trials, in each of which a group of good or choice feeder steers was fed a good ration in direct comparison with a group of medium feeder steers and also with a group of common steers.[91] The good to choice steers were high-grade beef cattle of good type, averaging 624 lbs. at the start. The medium steers were of the beef breeds, but were of less desirable type and were usually somewhat thinner, averaging 607 lbs. in weight. Many of the common feeders were of dairy breeds or showed some dairy blood. Although they were thrifty, they were thinner than the better grades and averaged only 550 lbs. in weight.

There was practically no difference in the rate of gain made by the various grades of cattle. The best grade averaged 2.31 lbs. a day, the medium feeders, 2.37 lbs., and the common feeders 2.35 lbs. Also, the feed cost per 100 lbs. gain was slightly the lowest for the common feeders, and a trifle lower for the medium feeders than for the good to choice feeders, which carried more flesh at the start. The average dressing percentage, in 5 experiments where this was determined, was only 56.9 per cent for the common feeders, while it was 58.7 per cent for the medium group and 60.6 per cent for the best cattle.

The average initial cost of the good to choice feeders in these tests was $2.34 more per 100 lbs. than for the common feeders, and $1.24 more than for the medium feeders. While the better cattle also sold for higher prices when fat, there was much less difference in the selling price than there was in the initial cost. The good to choice steers sold for only $1.16 more per hundredweight than the common grade, and the medium steers for only 68 cents more than the common cattle.

As a result of their cheaper gains and the greater margin, the net return per head over cost of feed was decidedly greater for the medium and for the common feeders than it was for the cattle of the better grades.

Unless the lower grade steers are well selected and are thrifty and growthy, their gains may be decidedly less rapid and more expensive than those of better-grade cattle. For example, in 3 Georgia experiments good feeders gained 2.42 lbs. per head daily, in comparison with only 1.89 lbs. for common feeders.[92] The feed cost per 100 lbs. gain was 6 per cent less for the good feeders.

1192. Choosing between the grades of feeder steers.—One should not conclude from the previous summary that the best profits are always made from buying the lower grades of feeder cattle. The financial outcome from the various grades will depend primarily on the margin that can be secured between their purchase price as feeders and their selling price as fat cattle.

The spread between the prices for good to choice fat cattle and for those of the lower grades is usually the greatest in summer and fall. This is because there are fewer such cattle then coming on the market. The spread is apt to be smallest in late winter and spring, when a large number of well-fattened cattle are coming to market from the feed lots.

In purchasing feeders one should not base his decision on the spread in price between the various grades of fat cattle at that time, but upon the difference there will probably be, based on average prices, when he has the cattle fattened and ready for market. If one has access to a special market that pays

a large premium for thoroughly fat cattle of high quality, obviously he cannot hope to secure the premium unless he fattens animals of the best grades. On the other hand, if the cattle are to be fattened chiefly on roughage, with but little grain, it will not pay to buy high-grade feeders, because they will not be fat enough to bring a top price when marketed.

In purchasing feeders of the lower grades it is especially important that they be carefully selected and that only thrifty animals be bought. Otherwise, the results may be disappointing. Some experienced feeders specialize in fattening cattle that do not even come up to the common grade. Such animals are in disfavor on the market, for most good stockmen do not want them on their premises. Hence, they can often be bought at a price that offers good possibilities of profit. Many such animals are unthrifty, and hence the death losses are higher than for good cattle. Also, more skill is necessary in feeding these cheap cattle. The fattening of such cattle should therefore be undertaken only by an expert who knows cattle and knows market conditions.

1193. Dairy steers vs. beef steers vs. crossbreds.—The question is often asked as to the value for beef of steers from the dairy breeds, especially Holsteins, in comparison with steers of the beef breeds. Experiments have shown that young dairy-bred steers make fairly good beef when well fattened. However, because of lower quality of carcass, they sell at a considerably less price on the market when fat. They are therefore worth much less per 100 lbs. as feeders than are well-bred beef steers.

In Michigan and Wisconsin trials Holstein steer calves made slightly more rapid gains, on the average, than did beef calves, because the Holsteins were thinner at the start.[93] In the Michigan trials the feed cost per 100 lbs. gain was a trifle higher for the Holsteins, but the reverse was true in the Wisconsin tests. The chief difference was in the selling price, for the Holstein steers brought $2.43 less per hundredweight when fattened than did the beef steers. The dressing percentage was 3.1 per cent lower for the Holsteins than for the beef steers.

In the Wisconsin experiments crossbred Holstein-Angus steer calves were also tested. They made desirable baby beeves, both on foot and when slaughtered, though they were not so smoothly covered with fat as Angus steers. However, their dressing percentage was about as high as for the Angus steers. Steers of the dual-purpose breeds yield better carcasses than dairy steers, but not usually equal to those from steers of the beef breeds.[94]

1194. Relation between conformation and gains.—It is well known that individual cattle of the same breed and age differ greatly in rate and economy of gains. Studies have been conducted to endeavor to find just what points of conformation are important as indications that an animal will make rapid and cheap gains and yield a high-grade carcass when fattened.[95] In these studies feeder cattle have been carefully measured and scored, and then records have been kept of the gains made by the individual animals, of the amounts of feed required per 100 lbs. gain, and of the quality of carcass yielded.

It has been found in most of these studies that the appearance of feeder cattle is not a reliable indication of their capacity to make rapid gains or economical gains. Experienced judges of cattle are generally much more successful in picking out young cattle that will yield high-quality carcasses when fattened, than they are in predicting just which animals will make the largest gains or require the least feed per 100 lbs. gain. They prefer animals that are deep, broad, and compact, with roomy digestive tracts and evidences of strong constitution. Cattle feeders also know that temperament is of great importance in the feed lot. The calm, quiet animal which eats its fill and then lies down is almost sure to outgain an animal that is nervous and restless.

These studies have shown that rate of gain is highly correlated with economy of gain. The cattle which make the most

rapid gains generally require less feed per 100 lbs. gain than do slower-gaining cattle.

In comparisons of large, medium, and small or compact type steers, the large or medium type cattle have usually made more rapid gains than those of small type, but the more compact cattle reach a given slaughter grade at a lighter weight.[96] If fattened to the same grade, there has not been an appreciable difference in the amounts of feed required per 100 lbs. gain. (1209)

Investigations by the United States Department of Agriculture and certain of the experiment stations show that marked improvement can be made in the efficiency of beef production by selecting young bulls on the basis of the rate and efficiency of gain in Record of Performance tests.[97] In this method of testing, bull calves are fed individually, after weaning, on a standard fattening ration, and the gains and feed efficiency accurately determined. An even more reliable basis of selection is by progeny testing, in which the offspring from various sires are similarly tested.[98] However, progeny testing has much more limited practical usefulness.

1195. Influence of age in fattening cattle.—It is well known that young animals require much less feed per pound of gain in weight than do older ones, and that their gains are decidedly cheaper. The reasons for this marked difference have been explained in Chapter IX. (265)

Comparison of calves, yearlings, and 2-year-olds

	Calves	Yearlings	2-year-olds
Av. initial wt., lbs.	414	638	840
Length of feeding periods, days	197	174	162
Av. daily gain, lbs.	2.19	2.26	2.40
Av. total gain, lbs.	431	393	389
Av. ration:			
Grain, lbs.	10.1	13.1	15.8
Supplement, lbs.	1.1	1.1	1.1
Hay, lbs.	4.2	5.4	5.8
Silage, lbs.	4.1	5.8	7.5
Total feed consumed per head:			
Grain, lbs.	1,990	2,279	2,552
Supplement, lbs.	217	188	170
Hay, lbs.	827	935	941
Silage, lbs.	808	1,014	1,221
Feed per 100 lbs. gain by steers:			
Grain, lbs.	462	586	667
Supplement, lbs.	47	45	41
Hay, lbs.	198	241	246
Silage, lbs.	186	258	308
Feed cost per 100 lbs.	$ 9.14 *	$10.98 *	$12.07 *
Initial cost per 100 lbs.	$ 8.78 *	$ 8.21 *	$ 8.24 *
Selling price per 100 lbs.	$10.32 *	$10.08 *	$10.14 *
Net return per steer	$ 9.39 *	$ 4.08 *	$ 3.25 *
Dressing percentage, per cent	58.9 †	59.8 †	60.7 †

* Average of 16 experiments.
† Average of 11 experiments.

On account of the great practical importance of the matter, many experiments have been conducted to compare the costs of gains and the net returns from fattening cattle of various ages. The table on this page gives the results secured in 17 experiments in which calves, yearlings, and 2-year-olds were

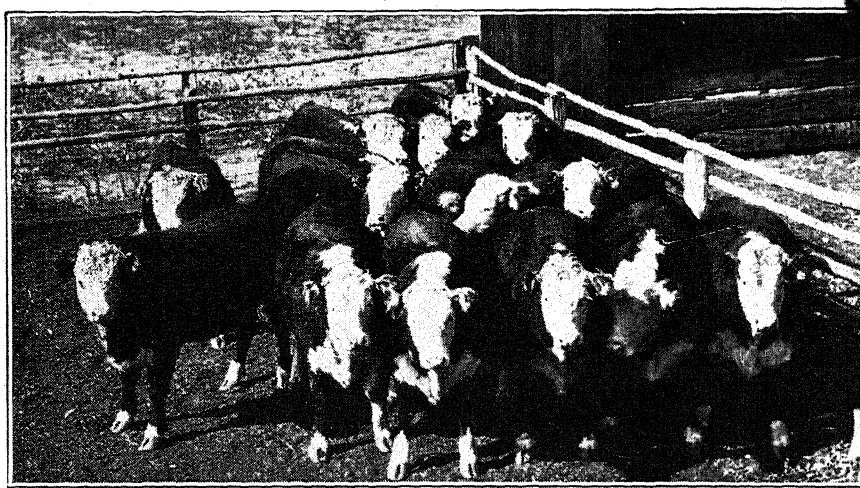
directly compared.[99] In these trials special efforts were made to secure feeder cattle of equal quality for the different ages. Cattle of good beef type and conformation were used in practically all the tests.

The cattle were fed grain (corn in all except one experiment) and legume or mixed hay. In addition they received a small allowance of protein supplement in certain of the tests, and had silage in addition to hay for roughage in 6 of the trials. Similar results have been secured in other experiments which did not include all the ages, or in which somewhat different rations were fed.[100]

An average of 197 days was needed to get the calves fat enough to meet market demands, while only 174 days were required for the yearlings and 162 days for the 2-year-olds. Often it will take 225 days or more to fatten calves properly, if they are thin when put on feed.

When young cattle are fed liberally from calf-hood, the daily gains will reach their maximum during the first year, and then the rate of gain will gradually decline. However, in the case of feeder cattle which are in thin condition when fattening begins, yearlings and 2-year-olds will make slightly more rapid gains than calves.

In these experiments the average daily gains were 2.40 lbs. for the 2-year-olds, 2.26 lbs. for the yearlings, and 2.19 lbs. for the calves. These are somewhat larger gains than are secured, on th average, in commercial cattle feeding, these experiments cattle of good qu were fed excellent rations under car supervision. Therefore, the data in table show the results that can



A FINE BUNCH OF BABY BEEVES

In baby beef production, well-bred beef calves must be fed a liberal amount of grain and a properly balanced ration. (From U.S. Department of Agriculture.)

cured by experienced stockmen and under favorable conditions.

These experiments were conducted when the prices of feeds and of cattle were much lower than now. The financial data in the table therefore merely show the relative feed cost per 100 lbs. gain for the different ages, and the relative cost of the feeder cattle and the relative selling prices.

There was not a great difference in the total gains, though a total of about 40 lbs. more gain was necessary to finish the calves properly than was required for the yearlings or 2-year-olds. Often, the total amount of gain needed to finish calves properly will be somewhat more

than was made by the high-quality calves in these experiments.

The amounts of feed eaten per head daily by the calves were considerably less than for the older cattle. However, since the calves were fed for a longer period, there was much less difference in the total amount of feed consumed by cattle of the different ages.

The economy of the younger cattle is shown by the amounts of feed required per 100 lbs. gain and by the feed cost per 100 lbs. gain. While the feed cost of each 100 lbs. of gain made by the calves was only $9.14, it was $10.98 for the yearlings and $12.07 for the 2-year-olds.

Calves usually cost more per 100 lbs. as feeders than do yearlings or 2-year-olds, and this is shown in these experiments. While the average initial cost of the yearlings and 2-year-olds was approximately the same, the cost of the calves was 57 cents per 100 lbs. higher than for the yearlings.

This greater initial cost of the calves was more than offset by their cheaper gains and by the further fact that they sold for a little higher price per hundredweight than the yearlings or the 2-year-olds. As a result, the average net return over the cost of feed, after allowing credit for the pork produced by the pigs following the cattle, was $9.39 per head for the calves, in comparison with $4.08 for the yearlings and $3.25 for the 2-year-olds.

Three-year-old cattle will usually require even more feed per 100 lbs. gain than 2-year-olds. Old cows generally do not make as rapid gains as yearlings or 2-year-olds, and their gains cost considerably more.[101]

TWO-YEAR-OLD STEERS BEING FATTENED ON PASTURE

Older cattle can be fattened chiefly on good pasture, with a minimum amount of grain.

1196. Which age of feeders should be purchased?—One should not conclude from the preceding summary that it is always more profitable to feed calves than older cattle. Whether or not this will be the case depends on the conditions at any particular time. In deciding which age of feeders to purchase, the following factors are important:

If the cost of yearling or 2-year-old feeders per 100 lbs. is enough below that of calves to offset fully the cheapness of the gains by calves, then the profit may be greater from feeding the older cattle.

Somewhat more care is necessary in

feeding calves than in the case of yearlings or 2-year-olds. Calves are not well suited to utilize roughage of poor quality. Therefore, if one wishes to use considerable corn stover, straw, or low-grade hay, he will prefer older cattle. Also, calves must have a liberal amount of grain to fatten properly, while 2-year-olds will reach a fair market finish on nothing but good corn silage, a little hay, and sufficient protein supplement.

Some people decidedly prefer the beef from well-finished older cattle of good quality to that from baby beeves, as it has more flavor. There is therefore still a definite demand for such carcasses. At certain times the supply is not sufficient to meet this demand, and then the price for fat yearlings or 2-year-olds of choice quality may be higher than that for baby beeves.

Calves have another advantage that is sometimes of importance, in addition to their cheaper gains and higher average selling price per hundredweight when well fattened. They will continue to make good gains for some time after the end of the ordinary feeding period, and if they are not continued on feed too long their carcasses will not be wastefully fat. Therefore, if the prices for fat cattle happen to drop at the time when it has been planned to market them, and one believes the prices will be better a few weeks later, calves can successfully be continued on feed for a reasonable length of time.

On the other hand, when 2-year-olds are already well fattened, further gains are very expensive. Also, the cattle will soon become so fat and heavy that they will not bring a satisfactory price, even if there is improvement in the general level of cattle prices.

1197. Efficiency of gains of cattle of various ages.—The most complete records of the amounts of feed consumed and the gains made by beef cattle from birth to market are those obtained by Haecker at the Minnesota Station.[102] So that all the feed consumed could be accurately determined, the calves were raised by hand, instead of nursing their dams.

During the various periods the steers were allowed all the roughage (corn silage and prairie hay) they would eat, but the amount of concentrates was somewhat smaller than is commonly fed to cattle that are being fattened for market. When the steers reached a weight of 1,200 lbs. they were sufficiently well fleshed for the market. Some were continued on trial until they reached 1,500 lbs. and were very fat.

The daily gains increased until the steers reached 600 lbs. in weight, after which they decreased slightly. The amount of feed required for 100 lbs. gain rose steadily as the steers grew and fattened. While only 225 lbs. total digestible nutrients were needed for 100 lbs. gain between the weights of 100 to 200 lbs., over 800 lbs. total digestible nutrients were required for 100 lbs. of gain after the steers reached 1,000 lbs.

The feed cost of 100 lbs. gain was higher for the first period than for those immediately following, because of the whole milk that was fed. The cost then rose gradually from $4.90 per 100 lbs. gain between 200 and 300 lbs. live weight up to $15.40 between the weights of 1,400 and 1,500 lbs. The feed cost of the gains was especially high after the steers had reached 1,200 lbs.

Though the older steers required more total digestible nutrients per 100 lbs. gain, they actually stored as much energy as did the younger ones for each 100 lbs. of total digestible nutrients they ate. They were therefore as efficient as the younger steers in converting food energy into energy of beef produced. The greater apparent efficiency of the young steers was entirely due to the fact that their gains were high in water and low in fat, while those of the older steers consisted chiefly of energy-rich fat.

In these studies it was found that the 1,200-lb. steers yielded in their carcasses 10.95 lbs. of edible meat and fatty tissues, containing 6.02 lbs. dry matter, for each 100 lbs. total digestible nutrients they had consumed during their growth and fattening. During the entire lives of these steers they converted about 10 per cent of the gross energy in the

feed they ate into the energy stored in their body tissues.[103] Thus, the "over-all" efficiency of the steers was 10 per cent.

1198. Excessive fattening wasteful.—Experienced cattle feeders know that it never pays to carry fattening cattle to an unnecessarily high "finish." After an animal is already well fattened, any further gains are much more expensive. This is because the gains then consist chiefly of fat and contain but little water. Also, after an animal has become fat, its appetite is less hearty, and consequently it eats less feed in proportion to its weight. It therefore has a smaller proportion of its food available for making gains, after the maintenance requirements have been met.

Not only are the gains exceedingly expensive when cattle are carried to extreme fatness, but also the carcasses from such animals do not meet the desires of most consumers. The lean meat will, it is true, be of the highest quality, but too large a proportion of the various cuts will consist of masses of fat which are not usually eaten.

Studies by the United States Department of Agriculture show that if cattle are fattened beyond the slaughter grade of "good," only a relatively small quantity of human food is produced during the additional period of fattening.[104] This is because most of the added gain is in the form of fat which is in excess of what the average person will eat along with the lean meat. It is estimated that to this degree of fatness, each 100 lbs. of grain fed produces about 6 lbs. of nutrients that are consumed directly as human food. In fattening cattle more, each additional 100 lbs. of grain fed produces only about 2 lbs. of added nutrients for humans.

The demand for highly-fattened steers is limited, even on the large central markets, for most consumers cannot afford this wasteful class of beef. Often such steers will bring some premium over those which are fattened only enough to yield desirable carcasses. However, unless one has a special market outlet for highly-fattened cattle, the difference in price is commonly so small that it fails to offset the high cost of carrying the steers to this degree of fatness.

The wise beef producer will therefore keep posted with reference to the market prices of the various grades of cattle and will sell his steers just as soon as they are sufficiently well fleshed to return the most profit. While it would be a source of pride to him to sell a load of steers that would "top the market," he knows that often this reduces rather than increases his net return.

1199. Heifers vs. steers; bulls.—On the large markets in the United States fat beef heifers commonly sell for a lower price than steers of similar quality and condition. However, experiments have proved that when young heifers are properly fattened but are not over-fat, they yield carcasses that are about equal to those from steers.[105] In these experiments there have been no appreciable differences due to sex in the dressing percentage, in the retail value of the carcasses, in the color of the meat, or in its tenderness and palatability when cooked.

Though heifers do not make as rapid gains as steers, they become fat sooner than steers and therefore do not require so long a feeding period. If fed for the length of time needed to finish steers properly, they become wastefully fat. Also, it does not usually pay to get heifers fat enough to reach the "choice" slaughter grade. If properly-finished heifers are sold at weights of not over 650 to 900 lbs., they will generally bring a better price than if fed to a heavier weight.

Heifers should therefore be marketed just as soon as they are fat enough to meet the market demands, which will be 2 to 3 months earlier than in the case of steers of the same age. Their gains will then generally cost no more per 100 lbs. than the gains of steers fed for the longer period.

In 7 experiments in which heifer calves have been fattened for an average of 165 days in comparison with steer calves fed for 239 days, the heifers gained an average of 2.23 lbs. a day and the steers only a trifle more, 2.27 lbs.[106] The average feed cost per 100 lbs. gain was the same for the heifers and the

steers. The initial cost of the heifers was 66 cents per hundredweight less than that of the steers, but the selling price when fattened was $1.36 less than for the steers. In these trials the net return per head was therefore considerably larger for the steers.

In other trials in which heifer calves or yearlings have been fattened for the same length of time as steers, the steers have gained decidedly more.[107] Also, they have required less feed per 100 lbs. gain, because they were not so fat.

Because the selling price of fat heifers is usually 50 cents to $2.00 less per 100 lbs. than for fat steers of equal quality, their initial cost per hundredweight must be decidedly lower, in order to secure as large a net return.

In fattening heifers for market, the practice is often followed of breeding them 3 to 4 months before they are to be marketed. This is done because bred heifers are less active and may require a little less feed per 100 lbs. gain. If heifers are no further advanced in pregnancy than this, there is no appreciable decrease in the value of the carcasses.[108] However, unless a buyer on the market can be certain that none of a particular lot of heifers is farther advanced in pregnancy than this, he must discount the price he offers, in order to be safe.

Spayed heifers are apt to make no better gains than open heifers, even after they have recovered from the effects of the operation.[109]

If possible, heifers should be fed apart from steers, to lessen the disturbance at the heat periods. However, in a Minnesota test about as good results were secured from a mixed lot of heifers and steers as from the two sexes fed separately.[110]

Bull calves fed a fattening ration make more rapid gains than steers or heifers and require less feed per 100 lbs. gain.[111] However, they are not so well fattened when fed for the same length of time, and sell at a decidedly lower price per hundredweight.

1200. Preparation of feeds.—The general principles which determine whether any particular method of feed preparation will prove profitable have been fully discussed in Chapter IV. Information is given in Chapters XX and XXI on whether or not it pays to grind each of the grains for beef cattle.

In general, the small grains should all be ground for beef cattle. In the case of corn, there is usually not enough saving through grinding to warrant the expense, if pigs follow the cattle to utilize any unchewed grain in the droppings. Also, calves chew corn so thoroughly up to 6 or 9 months of age that there is not much saving by grinding it for them.

Statements are sometimes made that rolling or crushing grain is preferable to grinding it. However, in several experiments with fattening cattle there has usually been little or no advantage in rolling or crushing over grinding.[112] Crushed or rolled grain is popular with herdsmen fitting cattle for show or sale, as it is somewhat more bulky than ground grain.

1201. Chopping or grinding dry roughage.—Experiments have shown that it does not generally pay to go to extra expense in chopping good-quality hay for beef cattle, when it is fed so as to avoid undue waste.[113] If hay can be stored in chopped form as cheaply as long hay, then chopping may be desirable. When hay is chopped for cattle, coarse chopping is decidedly preferable to fine chopping.

Chopping coarse-stemmed hay, such as much of the soybean hay, makes more saving than in the case of good alfalfa or clover hay. For example, in a Louisiana test chopping soybean hay for fattening cattle increased its value 25 per cent.[114] Shredding or chopping of corn or sorghum fodder or stover is advisable to lessen the waste, and also because the uneaten portion then makes much better bedding.

It does not generally pay to grind hay or other dry roughage for beef cattle, with the possible exception of sorghum fodder which contains considerable grain. Grinding is much more expensive than chopping, and in several tests has

generally made no more saving than chopping the roughage.[115] Processing sorghum fodder in a roughage mill that cracks the seed increases its value considerably more than merely chopping or shredding it.[116] However, the ground fodder generally has a much lower feeding value per acre than sorghum silage. (354)

In some of the western alfalfa districts where hay is usually cheap, it is commonly fed to fattening cattle in very liberal amounts. The wastage is hence greater than when only as much is supplied as will be cleaned up reasonably well. Chopped alfalfa hay was compared with uncut hay in 25 Idaho and Oregon comparisons in which fattening cattle were fed alfalfa hay, usually with a limited amount of grain or silage in addition.[117] On the average the cattle fed chopped hay gained 0.17 lb. more per head daily. From the standpoint of the amount of feed required per 100 lbs. gain, chopping the hay increased its value about 25 per cent.

For fattening cattle there is no advantage in mixing chopped or ground hay with the grain.[118] As shown in Chapter XXXI, this is sometimes done with fattening lambs heavily fed on grain, in order to lessen digestive disturbances.

1202. Pelleted or cubed feed.—This method of preparing cattle feeds is now attracting much attention. Although trials with beef cattle are limited, if increased feed intake is secured, improved performance is usually secured in terms of gain and feed efficiency. Responses are usually greatest where use is made of poor quality forages rather than high quality ones.

If pelleted cattle rations contain much less than 20 per cent roughage a reduction in feed intake and daily gain but increased feed efficiency may be secured. Fine grinding and pelleting of milo alone in a fattening ration has improved gains and feed efficiency slightly in Kansas experiments.

Pelleting or cubing of a concentrate mixture reduces wastage from wind or scattering when fed either in bunks or on the ground. Added cost may offset advantages of pelleting rations.

1203. Self-feeding.—When fattening cattle are to be fed all the grain they will eat, self-feeders are often used. As the hopper which holds the grain can be of considerable size, it requires less labor to keep it filled than to hand-feed the grain twice a day. Moreover, cattle generally gain a trifle more rapidly if self-fed than when hand-fed, even by experienced men.

There is also probably less tendency for self-fed cattle to "go off feed" than with those that are hand-fed. This is because each animal soon learns he can eat what he wishes at any time, and therefore there is not the tendency for greedy steers to gorge, as they sometimes do at feeding time when fed by hand.

These advantages are offset to some extent by the fact that more grain and less roughage are consumed per 100 lbs. gain by self-fed animals, and generally the gains are slightly more expensive than those of cattle hand-fed by a good stockman. However, the greater cost of the gains is usually offset by a higher selling price of the self-fed cattle, because of better finish.

A self-feeder should not be used when one wishes to utilize the maximum amount of roughage in fattening cattle. Also, ear corn is not well suited to self-feeding, as it tends to clog the feeder. It is therefore best to shell or grind corn for self-feeding.

In order to avoid digestive disturbances, cattle that are unused to grain are not usually self-fed grain separately until they have been brought to a full feed of grain by careful hand-feeding. Occasionally, chopped or ground hay is mixed with the grain in starting the cattle on the self-feeder. The grain in the self-feeder should be protected from rain or snow, and care is necessary to avoid clogging, as an abundance of feed should be available at all times.

When a protein supplement is used for self-fed cattle, the proper proportion of supplement is usually mixed with the

grain. If the supplement is fed free choice, the cattle are apt to eat more of it than is needed to balance the ration. However, in Oklahoma tests fattening calves did not overeat on protein supplement when self-fed, free choice, shelled corn, whole oats, and cottonseed meal, with prairie hay for roughage.[120]

Self-feeding of grain has been compared with hand-feeding in 13 experiments, in each of which one lot of cattle has been self-fed grain after they were safely on feed, while another lot was given the same grain by hand twice a day.[121] The roughages (hay or hay and silage) were hand-fed in the usual manner. Though expert cattlemen hand-fed the grain in these trials, the self-fed cattle gained 0.13 lb. more per head daily. While their feed cost per 100 lbs. gain was 26 cents higher, this was more than offset by a slightly higher selling price. On the average the net return per head over cost of feed was 87 cents per head more for the self-fed cattle, not considering the saving in labor. When cattle are fattened by less experienced men, there would usually be more advantage in self-feeding. In these trials self-feeding was just as well suited to the fattening of calves as of older cattle.

1204. Shelter; shade; hot weather.—Expensive buildings are not required for beef production. Even in a climate like that of the northern states, cattle make fully as rapid and economical gains when fattened during winter in an open shed with an adjacent exercise lot as when more warmly housed in a barn.[122] A reasonable degree of cold is a benefit rather than a detriment to liberally fed fattening cattle. This is because more heat is unavoidably produced in chewing, digesting, and assimilating their food than is needed to keep their bodies warm. (231)

In cold climates where there is considerable rain or snow during winter, it is advisable to provide a shed for shelter. Otherwise, the loss of heat in the evaporation of water from a wet skin, coupled with the loss by radiation, may be so great that food nutrients must be oxidized to keep the animal warm.

Unless the winters are unusually severe, it does not pay to provide warmer winter shelter than an open shed for beef breeding cows or for young stock, except very young calves. For cattle being fed little more than a maintenance ration, warmer shelter will save a small amount of feed in cold climates, but it is doubtful if the saving will be sufficient to justify much additional expense.[123]

In western regions where there is little rainfall, no shelter except a windbreak is commonly provided for beef cattle. Even where the winters are severe, furnishing shelter in an open shed or barn does not appreciably increase the gains of fattening cattle or save enough feed to justify the expense.[124]

In humid regions with mild winters, as in the southern states, it may likewise not pay to provide shelter for beef cattle.[125]

When cattle are fattened in a dry lot during the summer, it may be advisable to confine them to a barn or open shed, merely so that their coats do not become harsh and sunburned. Otherwise, the buyers at the central market may think that they have been fattened on grass and not offer the premium for them that cattle well fattened in the dry lot generally command.

Where the summers are very hot, it is important to provide shade for beef cattle, as has been shown in Chapter VIII.[126] (233) In the corn belt and eastward, there had best be shade for cattle on pasture, furnished either by trees or by a temporary shade. Opinions differ as to the value of shade for beef cattle in the range areas of the West, where the summers are less humid.[127]

Even when fattening cattle have shade, they usually make less rapid and economical gains in very hot weather than when it is cooler.[128]

1205. Confinement and exercise.—Beef breeding cattle and young stock being wintered should be allowed plenty of exercise in outside paddocks during the winter. Not only does the exercise itself aid in keeping them thrifty, but also the exposure to sunlight will prevent any deficiency of vitamin D. (201)

On the other hand, too much exercise for fattening cattle will make the gains less rapid and more expensive. Thus, in Kentucky trials fattening steers confined in winter to a barn and exercise lot made more rapid gains and gave a higher net return than others that had the run of a similar barn and were allowed to range at will on a 20-acre bluegrass pasture.[129]

The ordinary method of feeding fattening cattle in which they are fed as a group, having access to a common feed bunk and hay rack, is decidedly preferable to confining them in stanchions. Not only is there a saving of labor and equipment, but also the group-fed cattle will usually eat more feed, because of competition at the feed bunk, and make more rapid gains.[130] The group-fed cattle may, however, require a trifle more feed per 100 lbs. gain, because of their greater activity.

1206. The paved feed lot.—Where the soil and the climate are such that a feed lot will otherwise become a sea of mud and mire in winter, paving the lot will pay.[131] It will make the cattle more comfortable and will increase their gains, and also the pigs following the steers will be able to utilize the grain in the droppings more completely. In addition, there will be much less waste of manure.

1207. Dehorning.—Horned cattle are at a distinct disadvantage in the feedlot. They need more room than dehorned or polled cattle, they make less rapid gains, and they commonly sell at a lower price on the large markets, because of damage to hides and carcasses. It therefore pays well to dehorn feeder cattle before they are fattened for market.[132]

QUESTIONS

1. Why is it more necessary than formerly that beef cattle being fattened for market be fed well-balanced rations?
2. Compare the nutrient requirements of beef cows with those of dairy cows.
3. Compare the requirements of fattening cattle with those of cattle being carried through the winter for fattening later.
4. About how much will 100 lbs. of protein supplement, such as linseed meal or cottonseed meal, be worth for fattening cattle in comparison with grain, when added to a ration that has insufficient protein?
5. Discuss the addition of a protein supplement to grain and legume hay for fattening cattle.
6. Discuss the use of protein supplements with part non-legume roughage.
7. Under what conditions may the quality of protein in a protein supplement be of importance for fattening cattle?
8. How can urea be used satisfactorily as a substitute for part of the protein for beef cattle?
9. Discuss the value of certain combinations of protein supplements.
10. Discuss the requirements of beef cattle for: (a) Salt; (b) calcium; (c) phosphorus; (d) trace minerals.
11. What conditions are necessary for the successful self-feeding of a mixture of protein supplement and salt?
12. Discuss the requirements of beef cattle for vitamins, other than vitamin A.
13. When should a carotene or vitamin A supplement be fed beef cattle?
14. Why is good roughage important for beef cattle?
15. Discuss: (a) Adding a small amount of alfalfa to rations for fattening cattle; (b) Purdue Supplement A and other complex supplements.
16. Compare the value of supplements having only 20 to 30 per cent protein with that of a supplement having 40 per cent protein.
17. What results have been secured in experiments in which fat has been added to a ration for fattening cattle?
18. How much water do beef cattle need?
19. Should an antibiotic feed supplement be added to a ration for fattening cattle?
20. Discuss the use of stilbestrol for fattening cattle.
21. Under what conditions and for what ages of cattle is it economical to limit the amount of concentrates fed fattening cattle?
22. Define *margin* and *necessary margin.* State the effect of each of 5 factors on the necessary margin.
23. Discuss the value of beef blood for beef production, considering: (a) Rapidity and cost of gains; (b) early maturity; and (c) value of carcass.
24. How would you decide which grade of feeder steers to purchase?
25. What results have been secured in trials

in which beef-bred steers have been compared with dairy-bred steers?

26. What is known concerning the relation between the conformation of cattle and the rate and economy of gains?
27. Discuss the influence of age upon the economy of gains by beef cattle.
28. Upon what factors would you base your decision concerning the age of feeder cattle to buy?
29. Why is it important both for the beef producer and for the consumer not to carry fattening cattle to an excessive degree of fatness?
30. Discuss the results secured from the fattening of heifers.
31. Discuss the chopping of hay and other dry roughage for beef cattle; the grinding of roughage.
32. When is there an advantage in using pelleted feed for beef cattle?
33. When would you recommend the self-feeding of grain to fattening cattle?
34. Discuss the needs of beef cattle for shelter under various climatic conditions.
35. Contrast the requirements of breeding cattle and of fattening cattle for exercise.

REFERENCES

1. Guilbert, Gerlaugh, and Madsen, National Research Council, Recommended Nutrient Allowances for Domestic Animals, IV, 1945; see also: Winchester and Hendricks, U.S.D.A. Tech. Bul. 1071.
2. Hinman, Morrison, and Miller, N.Y. (Cornell) Rpts. 1933, 1934, 1935, and mimeo. rpts.
3. Mumford, Ill. Bul. 83; Skinner and Cochel, Ind. Buls. 115, 129; Skinner and Starr, Ind. Bul. 220; Skinner and King, Ind. Buls. 240, 249, 255, 265, 281, 291, 314; Allison, Mo. Bul. 112; Smith, Nebr. Buls. 90, 93.
4. Gramlich, Nebr. Bul. 174, and mimeo. rpt.
5. Thalman, Nebr. Bul. 345; Wilson and Wright, S.D. Buls. 293, 329; see also: Peters, Minn. Bul. 300; Blizzard, Okla. Bul. 237; Jacob, Tenn. Rpt. 1938.
6. Thalman, Nebr. Bul. 345.
7. Skinner and Cochel, Ind. Buls. 129, 136; Mumford, Ill. Bul. 103; Culbertson and Evvard, Iowa, Amer. Soc. Anim. Prod., Proc. 1923; Peters and Carnes, Minn. Bul. 200.
8. Hickman, Rinehart, and Johnson, Id. Bul. 209; Dickson, Mont. Bul. 359; Potter, Withycombe, and Edwards, Ore. Bul. 276; Ore. Bul. 401; see also: Stanley and Walker, Ariz. Bul. 170.
9. Branaman, Mich. Spec. Bul. 280; Peters, Minn. Bul. 300; Bohstedt, Ohio Bimo. Bul. 117; see also: Skinner and King, Ind. Bul. 429.
10. McCampbell et al., Kan. Cirs. 107, 117, 128.
11. Allison, Mo. Bul. 150; Gramlich, Nebr., mimeo. rpt.
12. Skinner and Cochel, Ind. Bul. 129; Skinner and Starr, Ind. Bul. 220; Skinner and King, Ind. Buls. 240, 249, 255, 265, 281, 291, 314; Allison, Mo. Bul. 112; see also: Culbertson, Evvard, et al., Iowa, Amer. Soc. Anim. Prod., Proc. 1923; Bohstedt, Ohio Bimo. Bul. 105–106.
13. Pope et al., Okla. Bul. B-428.
14. Guilbert, Hart, and Wagnon, Cal. Agr., Feb. 1948; Kirk, Fla., Jour. Anim. Sci., 11, 1952, p. 769; Levy and Donker, Ga., Jour. Dairy Sci., 38, 1955, p. 624; Johnson, Keith, and Lehrer, Id. Bul. 225; Ill. 24th Cattle Feeders' Meeting, mimeo. rpt.; Forbes, Neumann, and Garrigus, Ill., Jour. Anim. Sci., 14, 1954, p. 1206; Beeson and Perry, Ind., Jour. Anim. Sci., 11, 1953, pp. 501–[illegible]; Culbertson, Shearer, Hammond, and M[illegible], Iowa, A.H. Mimeo. Rpt. 176; Ga[illegible], Long, and Thompson, Ky., 9th D[illegible] Feed Conf., 1954; Tillman, Singletar[illegible] well, and Bray, La., Jour. Anim. Sc[illegible], 1951, pp. 939–946; Brown, Damon, V[illegible], and Singletary, La. Rpt. 1952; VanA[illegible], Hoefer, Branaman, and Luecke, Mich. Q[illegible] Bul. 36, 1953, No. 1; Harvey et al., Min[illegible] mimeo. rpt.; Thomas, Clanton, and Willson, Mont., Jour. Anim. Sci., 12, 1953, p. 933; Brouse, Nebr. Bul. 357 (Revised); Baker, Arthaud, and Gregory, Nebr. Rpt. 62; Dowe, Arthaud, Gregory, and Baker, Nebr. Rpt. 63; Baker and Jackson, Nebr., North Platte Prog. Rpt. 67; Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732; Gallup, Pope, and Whitehair, Okla. Bul. B-409; Embry and King, S.D. Farm and Home Res., 4, 1953, No. 2; Bell, Murphree, and Hobbs, Tenn., Jour. Anim. Sci., 13, 1954, p. 976; Bell, Reynolds, Hobbs, and Odom, Tenn. Farm and Home Sci., Prog. Rpt. 10; Tex. Bul. 724; Schoonover, Stratton, Hilston, and Paules, Wyo. Mimeo. Cir. 34; Grover, Stratton, Hilston, and Paules, Wyo. Mimeo. Cir. 49; Watson et al., Canada, Sci. Agr., 29, 1949, pp. 173–184; McCall and Graham, Jour. Anim. Sci., 11, 1952, pp. 770–771.
15. Gallup, Pope, and Whitehair, Okla. Bul. B-409; Ross et al., Okla. Misc. Pubs. MP-11, MP-13, MP-17, MP-22; Ross, MacVicar, and Stephens, Okla. Bul. B-359; Long et al., Okla. Misc. Pub. MP-27; Nelson, Long, MacVicar, and Bratcher, Okla. Misc. Pub. MP-34; Nelson, Long, and MacVicar, Okla. Misc. Pub. MP-43.
16. Kirk, Peacock, Hodges, and Jones, Fla. Rpt. 1953.
17. Skinner and King, Ind. Bul. 433; Culbertson and Hammond, Iowa Rpt. 1931; Gerlaugh and Hackett, Ohio Bimo. Bul. 146.
18. Brouse, Nebr. Bul. 357 (Revised).
19. Pope, Stephens, Darlow, and MacVicar, Okla. Misc. Pub. MP-22.
20. Briggs, Gallup, and Darlow, Okla., Jour. Agr. Res., 73, 1946, pp. 167–176.
21. Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732.
22. Evvard, Culbertson, et al., Iowa Rpt. 1931, Iowa Leaflet 16, and mimeo. rpts.
23. Parrish, Kan., mimeo. rpt.
24. Smith and Parrish, Kan. Rpt. 1948–50; Smith, Parrish, and Clawson, Kan. Cir. 273; Smith, Parrish, and Splitter, Kan. Cirs. 283, 297, and mimeo. rpts.

24a. Stanley, Pahnish, and Safley, Ariz. Mimeo. Rpt. 105.

25. Evvard, Iowa, Breeder's Gazette, 76, 1919, p. 307; Evvard, Culbertson, et al., Iowa, mimeo. rpts.; see also: Becker, Neal, and Shealy, Fla. Bul. 231; Jacob and Duncan, Tenn. Bul. 156.
26. Hensel, Kan., Breeder's Gazette, 80, 1921, p. 181; Kan. Rpt. 1920–22.

27. McCampbell et al., Kan. Fort Hays Branch Sta., Cattlemen's Round-up, 1927.
28. Chapline and Talbot, U.S.D.A. Cir. 379; see also: Stanley, Ariz. Tech. Bul. 79; Kirk, Fla. Rpt. 1952; Smith, Parrish, and Splitter, Kan., mimeo. rpt.; Tex. Bul. 724.
29. Cardon, Stanley, Pistor, and Nesbitt, Ariz. Bul. 239; Meyer, Weir, Ittner, and Smith, Cal., Jour. Anim. Sci., 14, 1955, pp. 412–418; Kirk and Peacock, Fla. Rpt. 1953; Smith, Cox, and Fansher, Kan. Cir. 297; Miss. Rpt. 66; New Mex. Rpt. 62; Nelson et al., Okla. Bul. B-440; Riggs, Colby, and Sells, Tex., Jour. Anim. Sci., 12, 1953, pp. 379–393; Galgan and Schneider, Wash. Stas. Cir. 166; McIlvaine, U.S.D.A. Agr. Res., 3, 1954, No. 1; Savage, U.S.D.A., mimeo. rpt. Morton, Osland, and Tom, Colo. Press Bul. 88; Skinner and King, Ind. Bul. 429; Blizzard, Okla. Bul. 179; Jones, Bayles, Jones, and Black, Tex. Rpt. 1934.
31. McCampbell, Kan., Amer. Soc. Anim. Prod., Proc. 1932; Weber, McCampbell, Hughes, and Peterson, Kan. Tech. Bul. 51; Hall, Mackintosh, and Vail, Kan. Tech. Bul. 58; Blizzard, Okla. Bul. 237; Jones et al., Tex. Rpts. 1932, 1933, 1934; see also: Skinner and King, Ind. Bul. 433; Jones, Jones, and Bayles, Tex. Bul. 604.
32. Rusk and Snapp, Ill. Rpt. 1935; Tex. Bul. 724.
33. Lewis, Burkitt, and Willson, Mont., Jour. Anim. Sci., 10, 1951, p. 1053; Brouse, Nebr. Bul. 357; Dowe, Nebr. Quarterly, 2, 1953, No. 2.
34. Matsushima et al., Nebr. and Tenn., Jour. Anim. Sci., 14, 1955, pp. 1042–1049.
35. Hall, Mackintosh, and Vail, Kan. Tech. Bul. 58.
36. Hickman, Rinehart, and Johnson, Id. Buls. 209, 220; Rusk and Snapp, Ill. Rpt. 1928; Skinner and King, Ind. Buls. 281, 291, 314; McCampbell et al., Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1933; Dickson, Mont. Bul. 359; Baker and Jackson, Nebr., North Platte Sta. Prog. Rpt. 67; Bohstedt, Ohio Buls. 373, 382; Darlow et al., Okla. Bul. B-372; Aune, S.D. Rpt. 1938; Wyo. Rpt. 1933.
37. Beeson, Bolin, Hickman, and Johnson, Id. Bul. 240; Beeson et al., Id. Buls. 251, 255, 268; Thomas, Clanton, and Willson, Mont., Jour. Anim. Sci., 12, 1953, p. 933; Hoffman, Bogart, and Burris, Ore. Bul. 528; Jones, Keating, Ellis, and Crookshank, Tex. Prog. Rpt. 1570; Maynard, Greaves, and Smith, Utah Bul. 265.
38. Stanley, Ariz. Tech. Bul. 79; Mich. Spec. Bul. 348; Darlow et al., Okla. Bul. B-372; Stoddart, Utah Bul. 314; Savage and Heller, U.S.D.A. Tech. Bul. 943.
39. Black, Tash, Jones, and Kleberg, U.S.D.A. Tech. Bul. 856; Reynolds, Jones, Jones, Fudge, and Kleberg, Tex. Bul. 773; see also: Brouse, Nebr. Bul. 357.
40. Knox, Benner, and Watkins, New Mex. Buls. 282, 331; Knox, Watkins, Koger, and Valentine, New Mex. Bul. 359; see also: Nelson, Gallup, Ross, and Darlow, Okla. Tech. Bul. T-54.
41. Beeson, Bolin, Hickman, and Johnson, Id. Bul. 240.
42. Wheeler, Wyo. Bul. 269; see also: Watkins, New Mex. Bul. 212.
43. Fudge and Fraps, Tex. Bul. 669.
44. Plumlee, Totusek, and Beeson, Ind., Jour. Anim. Sci., 12, 1953, p. 928; Miss. Rpt. 66; Thomas, Clanton, and Willson, Mont., Jour. Anim. Sci., 12, 1953, p. 933; Dowe, Matsushima, Arthaud, and Jillson, Nebr. Cattle Prog. Rpt. 224; Baker and Jackson, Nebr., North Platte Prog. Rpt. 67; Nelson, Totusek, Gallup, and Swader, Okla. Misc. Pub. MP-43; Galgan, Ensminger, Schneider, and Patterson, Wash. Stas. Cir. 164; Schoonover, Stratton, Hilston, and Paules, Wyo. Mimeo. Cir. 34.
45. Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732; Embry, S.D., 12th Livestock Feeders' Day Rpt.
46. Colo. Rpt. 63.
47. Safford, Swingle, and Marsh, Mont., Amer. Jour. Vet. Res., 15, 1954, p. 373; Safford and Swingle, Mont., Amer. Jour. Vet. Res., 16, 1955, pp. 64–68; Vawter and Records, Nev., Jour. Amer. Vet. Med. Assoc., 110, 1947, pp. 152–157; Ore. Buls. 477, 491; Shaw, Ore. Bul. 508.
48. Guilbert and Hart, Cal., Jour. Nutr., 10, 1935, pp. 409–427; Moore, Mich., Jour. Dairy Sci., 22, 1939, pp. 803–812; N.C. Rpt. 1938; Church, Pope, and MacVicar, Okla., Jour. Anim. Sci., 14, 1955, p. 1197; Jones et al., Tex. Buls. 630, 639; Davis and Madsen, U.S.D.A., Jour. Nutr., 21, 1941, pp. 135–146; Madsen and Davis, U.S.D.A., Jour. Anim. Sci., 8, 1949, pp. 625–626.
49. Ruby, Ray, and Mabry, Ark. Bul. 515; Ariz. Rpt. 1948.
50. Jones et al., Tex. Bul. 630; Tex. Bul. 724.
51. Klosterman, Bolin, and Ford, N.D. Bimo. Bul., 13, 1951, No. 3.
52. Church et al., Okla. Misc. Pub. MP-43.
53. Watkins and Knox, New Mex., Jour. Anim. Sci., 13, 1954, pp. 490–495; Davis and Kirk, Fla. Rpt. 1950.
54. Hart and Guilbert, Cal. Bul. 560; Hart, Guilbert, Wagnon, and Goss, Cal. Bul. 699.
55. Creech and Madsen, U.S.D.A., The Bureau Veterinarian, 18, 1942, No. 1; see also: Duitsman and Kessler, Kan. Cir. 322; Baker, Loeffel, and Hanson, Nebr. Rpts. 59, 60; Dow, Matsushima, and Arthaud, Nebr. Rpt. 64.
56. Gramlich and Thalman, Nebr., mimeo. rpt.
57. Rusk and Snapp, Ill. Rpt. 1932.
58. Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732; see also: Baker and Clawson, Nebr., North Platte Prog. Rpt. 65; Baker and Jackson, Nebr., North Platte Prog. Rpt. 70; Pope, Bennett, Heller, and Campbell, Okla. Misc. Pub. MP-43; Nelson, Long, MacVicar, and Campbell, Okla. Misc. Pub. MP-43.
59. Beeson, Perry, et al., Ind. Mimeo. Rpts. A.H. 48, 54, 58, 63, 64, 66, 123; Beeson and Perry, Ind., Jour. Anim. Sci., 11, 1952, pp. 501–515.
60. Ill. 24th Cattle Feeders' Meeting, mimeo. rpt.; Richard, Langford, Douglas, and Buchanan, N.D. Bimo. Bul., 16, 1954, No. 6; Klosterman, Sutton, and Moxon, Ohio Anim. Sci. Mimeo. Rpt. 79; Pope, Humphrey, Stephens, and Heller, Okla. Misc. Pub. MP-34; Pope, Humphrey, Walters, and Heller, Okla. Misc. Pub. MP-43; Bell, Reynolds, Hobbs, and Odom, Tenn. Farm and Home Sci. No. 10; Kincaid, Copenhaver, and McClaugherty, Va. Rpt. 1950–53; see also: Connell, Colo. Farm and Home Sci., 4, 1953, No. 1; 4, 1954, No. 6; Duitsman and Kessler, Kan. Cir. 322; Luecke, Mich. Quar. Bul., 36, 1953, No. 1; Miss. Rpt. 66; Brouse, Nebr. Bul. 357; Langford and Douglas, N.D. Bimo. Bul., 17, 1955, No. 6.
61. Gerlaugh et al., Ohio Bul. 532.
62. Burroughs, Iowa, Feed Bag, February, 1955.

63. Nelson et al., Okla. Bul. B-437; Nelson, MacVicar, Campbell, and Ross, Okla. Bul. B-460; see also: Kelley, Smith, and Martin, Ala. Leaflet 47
64. Smith, Good, and Anderson, Kan. Rpt. 1948–50.
65. Willey et al., Tex., Jour. Anim. Sci., 11, 1952, pp. 705–711.
66. Hentges, Pearson, and Tucker, Fla., Jour. Anim. Sci., 13, 1954, p. 970.
67. Matsushima, Dowe, Adams, and Arthaud, Nebr. Cattle Prog. Rpts. 219, 221.
68. Hickman, Rinehart, and Johnson, Id. Bul. 209; Heinton, Foster, and Gobble, Ind. Rpt. 1941; Foster, Ind. Cir. 298; Potter and Withycombe, Ore. Bul. 183.
69. Gerlaugh, Ohio Bimo. Buls. 159, 166.
70. Stanley, Ariz. Tech. Bul. 79.
71. Hentges, Black, Tucker, and Cunha, Fla., Jour. Anim. Sci., 14, 1955, p. 1207; Neumann, Snapp, and Gall, Ill., Jour. Anim. Sci., 10, 1951, pp. 1058–1059; Perry, Beeson, Hornback, and Mohler, Ind., Jour. Anim. Sci., 13, 1954, pp. 3–9; Burroughs et al., Iowa Mimeo. Rpt. A.H. 662; Duitsman and Kessler, Kan. Cir. 307; Totusek and Lynd, Okla. Misc. Pub. MP-34; Totusek, Shroder, and Pope, Okla. Misc. Pub. MP-43; Marion, Fisher, and Jones, Texas, Feed Bag, December, 1954; McElroy and Berg, Univ. of Alberta, Canada, 34th Feeders' Day Rpt.; Johnson, Elliott, and Shor, Jour. Anim. Sci., 14, 1955, p. 1211; Adams, Reynolds, Sherman, and Luther, Jour. Anim. Sci., 14, 1955, p. 1242.
72. Horn, Snapp, and Gall, Ill., Jour. Anim. Sci., 14, 1955, pp. 243–248; Lassiter, Denton, Davis, and Taylor, Ky., Jour. Anim. Sci., 13, 1954, p. 991; Bell, Whitehair, and Gallup, Okla., Jour. Anim. Sci., 9, 1950, pp. 647–648.
73. Md. Bul. A-78.
74. Clegg, Albaugh, Strong, and Cole, Cal. Cir. 441; Simone, Carroll, Hinreiner, and Clegg, Cal. Agr., 9, 1955, No. 11; O'Mary, Warren, Davis, and Pierce, Ga., Jour. Anim. Sci., 15, 1956, pp. 52–58; Dinusson, Andrews, and Beeson, Ind., Jour. Anim. Sci., 9, 1950, pp. 321–330; Andrews, Beeson, and Johnson, Ind., Jour. Anim. Sci., 13, 1954, pp. 99–107; Deans, VanArsdell, Reineke, and Bratzler, Mich., Jour. Anim. Sci., 12, 1953, p. 901; Klosterman, Bentley, Moxon, and Kunkle, Ohio Anim. Sci. Mimeo. Series 94; Klosterman, Cahill, Kunkle, and Moxon, Ohio, Jour. Anim. Sci., 14, 1955, pp. 1050–1058; Luther et al., Jour. Anim. Sci., 13, 1954, p. 1025; see also: Burris et al., Ore. Tech. Bul. 31.
75. Burroughs et al., Iowa, Science, 120, 1954, p. 66; Burroughs et al., Iowa, Jour. Anim. Sci., 14, 1955, pp. 1015–1024.
76. Mitchell, Albert, Staheli, and Neumann, Ill., Jour. Anim. Sci., 14, 1955, p. 1218; Perry, Beeson, Andrews, and Stob, Ind., Jour. Anim. Sci., 14, 1955, pp. 329–335; Perry, Andrews, Stob, and Beeson, Ind., Jour. Anim. Sci., 14, 1955, p. 1253; Klosterman, Bentley, Moxon, and Kunkle, Ohio Anim. Sci. Mimeo. Ser. No. 94; Murfree, Tenn. Farm and Home Sci., Prog. Rpt. 13; Luther et al., Jour. Anim. Sci., 13, 1954, p. 1025; see also: Duitsman and Kessler, Kan. Cir. 322.
77. Preston et al., Iowa, Jour. Anim. Sci., 15, 1956, pp. 3–12; Turner, Mo., Jour. Anim. Sci., 15, 1956, pp. 13–24
78. Dinusson, Andrews, and Beeson, Ind., Jour. Anim. Sci., 9, 1950, pp. 321–330; Schroder, Pope, Humphrey, and MacVicar, Okla. Misc. Pub. MP-43.
79. Skinner, King, et al., Ind. Buls. 206, 220, 240, 249, 255, 265, and mimeo. rpt.; Evvard and Dunn, Iowa, mimeo. rpt.; Evvard, Culbertson, Wallace, and Hammond, Iowa Bul. 253; Peters and Carnes, Minn. Bul. 200; Trowbridge, Mo. Bul. 179; Trowbridge and Fox, Mo. Bul. 218; Gramlich, Nebr., mimeo. rpt.; Bohstedt, Ohio, mimeo. rpt.; Fuller and Morrison, Wis. Bul. 319, and mimeo. rpt.
80. McCampbell and Winchester, Kan. Cir. 77; Trowbridge and Fox, Mo. Buls. 189, 197; Tomhave and Bentley, Penn. Buls. 181, 183; Ziegler, Bentley, and Miller, Penn. Bul. 307; Quayle and Paules, Wyo. Bul. 308.
81. Evvard, Culbertson, et al., Iowa, mimeo. rpt.; Culbertson and Hammond, Iowa, mimeo. rpt.; McCampbell, Winchester, and Marston, Kan. Cirs. 86, 92, 97; Branaman, Mich. Spec. Bul. 280; Vaughan, Minn. Bul. 237; Thalman and Gramlich, Nebr., mimeo. rpt.; Bohstedt, Ohio Bimo. Buls. 117, 123; Jacob, Tenn. Rpts. 1936, 1938; Texas Bul. 724.
82. Skinner, King, et al., Ind. Buls. 206, 220, 240, 249, 255, 265; Trowbridge et al., Mo. Buls. 218, 413; see also: King et al., Ind. Rpts. 1943, 1944, 1945; Culbertson, Shearer, and McClurg, Iowa Rpts. 1944, Part 2; 1945, Part 2.
83. Skinner, King, et al., Ind. Buls. 206, 220, 240, 249, 255, 265; Dunn, Evvard, and Pew, Iowa Bul. 182; Trowbridge and Fox, Mo. Bul. 218; Bohstedt, Ohio Bimo. Buls. 83–84, 93–94; see also: Anderson, McCampbell, and Alexander, Kan. Cir. 151; Christensen, N.D., mimeo. rpt.; Vinke and Pearson, Mont. Bul. 251; Sackville and Bowstead, Univ. of Alberta, Canada, Col. of Agr., Bul. 13, Sackville and Sinclair, Univ. of Alberta, mimeo. rpt.; see also: Stanley, Ariz. Bul. 198; Knox and Neale, New Mex. Buls. 262, 310; N.C. Rpt. 1945; Gerlaugh and Gay, Ohio Bimo. Bul. 198; Black, Howe, Jones, and Keating, U.S.D.A. Tech. Bul. 847.
84. Ariz. Rpts. 1950, 1951; Connell, Colo. Farm and Home Res., 4, 1953, No. 3; Keith, Johnson, and Lehrer, Id. Bul. 290; Id. Res. Bul. 26; Weber, Aicher, and Kessler, Kan. Cir. 260; Richardson, Smith, and Cox, Kan. Cirs. 297, 308; Dove, Arthaud, and Matsushima, Nebr. Rpt. 64; Knox, New Mex. Bul. 367.
85. Stanley, Ariz. Bul. 108; Knox and Neale, New Mex. Bul. 310.
86. Williams, Ariz. Bul. 91; Hickman, Rinehart, and Johnson, Id. Bul. 209; Vinke and Pearson, Mont. Bul. 251; Foster and Simpson, New Mex. Bul. 101; Potter and Withycombe, Ore. Bul. 193; Carroll, Utah, information to the author; Hackedorn, Sotola, and Bean, Wash. Bul. 208.
87. Hickman, Rinehart, and Johnson, Id. Bul. 209; Potter and Withycombe, Ore. Bul. 193.
88. Williams, Ariz. Bul. 91; Hickman, Rinehart, and Johnson, Id. Bul. 209; Potter and Withycombe, Ore. Bul. 193; Hackedorn, Sotola, and Bean, Wash. Bul. 208.
89. Burch, U.S.D.A., Bur. Anim. Indus., press announcement.
90. Hawkins, Blizzard, and Croft, Okla. Rpt. 1932–34; see also: Dvorachek and Semple, Ark. Bul. 247; Edwards and Massey, Ga. Bul.

184; Collison, Miss. Bul. 347; Hostetler, Foster, and Case, N.C. Rpts. 1929, 1931, 1932; Semple and Dvorachek, U.S.D.A. Tech. Bul. 203.

91. Evvard, Culbertson, et al., Iowa, mimeo. rpt.; Peters, Minn. Bul. 300; Gerlaugh and Gay, Ohio Bimo. Buls. 152, 158, 166, 173; Bentley and Ziegler, Penn. Bul. 329; Knox, Tex., Amer. Soc. Anim. Prod., Proc. 1931; see also: Stanley, Ariz. Bul. 198; Mumford, Ill. Bul. 90; Rusk and Snapp, Ill. Rpt. 1932; Francis, Bull, and Carroll, Ill. Bul. 501; Culbertson, Hammond, and Shearer, Iowa, mimeo. rpt.; McCampbell and Winchester, Kan. Cir. 92; Gramlich, Nebr. Rpt. 1922 and mimeo. rpts.; Gerlaugh, Klosterman, and Kunkle, Ohio Res. Cir. 26; Livesay, West Va. Bul. 225; Black, Warner, and Wilson, U.S.D.A. Tech. Bul. 217; Dowell, Bowstead, and Black, Univ. of Alberta, Canada, mimeo. rpts.

92. Black and Southwell, U.S.D.A. Tech. Bul. 904.

93. Branaman and Brown, Mich. Quar. Bul., 20, 1937, No. 1; Fuller, Wis. Buls. 396, 405, 410; Fuller, Wis., Amer. Soc. Anim. Prod., Proc. 1930; see also: Williams, Ariz. Bul. 91; Baker, Nebr., North Platte Sta. Prog. Rpts. 53, 55, 58; Kidwell and McCormick, Nev., Jour. Anim. Sci., 15, 1956, pp. 109–118; Bohstedt, Ohio Bimo. Bul. 83–84; Hayden, Ohio Bimo. Bul. 89–90; Deatherage and Kunkle, Ohio Bul. 705; Stoddart, Utah Bul. 314.

94. Dow, Arthaud, and Adams, Nebr. Rpt. 63; Matsushima, Adams, and Arthaud, Nebr. Cattle Prog. Rpt. 210; see also: Matsushima, Anderson, Harvey, and Aunan, Minn., Jour. Anim. Sci., 8, 1949, pp. 612–613.

95. Stanley and McCall, Ariz. Tech. Bul. 109; Guilbert and Gregory, Cal., Jour. Anim. Sci., 3, 1944, pp. 145–153; Stonaker, Colo. Farm and Home Res., 3, 1953, No. 5; Bell, Smith, and Smith, Kan. Cirs. 283, 297; Peters and Johnson, Minn., mimeo. rpt.; Woodward, Clark, and Cummings, Mont. Bul. 401; Smith, Nebr. Bul. 132; Bliss and Lee, Nebr. Bul. 151; Kidwell, Nev., Jour. Anim. Sci., 14, 1955, pp. 233–242; Durham and Knox, N. Mex., Jour. Anim. Sci., 12, 1953, pp. 771–774; Bogart, Ore. Bul. 508; Severson and Gerlaugh, Penn. Rpt. 1917; Lush, Tex. Buls. 385, 471; Baker, Colby, and Lyman, Tex., Jour. Anim. Sci., 10, 1951, pp. 726–732; Hultz, Wyo. Bul. 153; Hultz and Wheeler, Wyo. Bul. 155; Black, Knapp and Cook, U.S.D.A., Jour. Agr. Res., 56, 1938, pp. 465–472; Knapp and Baker, U.S.D.A., Jour. Anim. Sci., 3, 1944, pp. 219–223; Kohli, Cook, and Dawson, U.S.D.A., Jour. Anim. Sci., 10, 1951, pp. 352–364; Knapp and Clark, U.S.D.A., Jour. Anim. Sci., 10, 1951, pp. 365–370; Yao, Dawson, and Cook, U.S.D.A., Jour. Anim. Sci., 12, 1953, pp. 775–786.

96. Stonaker, Ingalls, and Wheeler, Colo., Jour. Anim. Sci., 11, 1952, pp. 17–25; Weber, Mackintosh, Good, and Smith, Kan. Cir., 273; Knox, Watkins, Koger, and Valentine, N. Mex. Bul. 359; Chambers, Whatley, and Stephens, Okla. Misc. Pub. MP-34; Willey et al., Texas, Jour. Anim. Sci., 10, 1951, pp. 195–202; Wyo. Rpt. 59; Amer. Hereford Jour., Mar. 15, 1951.

97. Shelby, Clark, and Woodward, U.S.D.A., Jour. Anim. Sci., 14, 1955, pp. 372–385; Willson and Flower, Mont. Bul. 487; Chambers et al., Okla. Misc. Pub. MP-43; Pierce, Avery, Burris, and Bogart, Ore. Tech. Bul. 33; Bennett and Matthews, Utah Bul. 377; Galgan, Ensminger, and Kyd, Wash. Stas. Cir. 204.

98. Shelby, Clark, and Woodward, U.S.D.A., Jour. Anim. Sci., 14, 1955, pp. 372–385; Stanley and McCall, Ariz. Tech. Bul. 109; Winters and McMahon, Minn. Tech. Bul. 94; Clark and Knapp, Mont. Bul. 417; Ore. Bul. 477; Dinkel, S.D., mimeo. rpt.; Roubicek, Hilston, and Wheeler, Wyo. Bul. 307; see also: Kincaid, Carter and Copenhaver, Va., Jour. Anim. Sci., 11, 1952, p. 741.

99. Culbertson, Evvard, Hammond, and Bassett, Iowa Bul. 271 and mimeo. rpts.; Peters, Minn. Bul. 300; Gramlich, Nebr. Bul. 229; Gramlich and Thalman, Nebr. Bul. 252; Bohstedt, Ohio Bimo. Buls. 83–84, 93–94, 105–106; McCall and Hackedorn, Wash. Bul. 352.

100. Stanley and Scott, Ariz. Bul. 108; Stanley and Walker, Ariz. Bul. 170; Howell, Cal. Bul. 421; Hickman, Rinehart, and Johnson, Id. Bul. 209; Rusk and Snapp, Ill. Rpt. 1932; McCampbell, Bell, and Winchester, Kan. Cir. 77; Weber, McCampbell, and Cathcart, Kan. Rpt. 1938–40; Bray, La. Bul. 296; Trowbridge and Fox, Mo. Buls. 197, 210, 228, 272; Arnett, Mont. Rpt. 1923; Quesenberry, Baker, Krantz, and Hutton, Mont. Rpt. 1927; Hungerford and Foster, New Mex. Bul. 128; Snell, New Mex. Bul. 140; Hostetler and Foster, N.C. Rpt. 1936; Tenn. Rpt. 1951; Jones, Lush, and Jones, Tex. Bul. 309; Livesay, West Va. Bul. 251; Sackville and Bowstead, Univ. of Alberta, Canada, Col. of Agr. Bul. 12.

101. Stanley and Scott, Ariz. Bul. 108; Rusk and Snapp. Ill. Rpt. 1932; Trowbridge and Moffett, Mo. Bul. 300; Gramlich and Thalman, Nebr., mimeo. rpt.

102. Haecker, Minn. Buls. 155, 193.

103. Armsby and Moulton, The Animal as a Converter of Matter and Energy, pp. 217–218.

104. Nelson, U.S.D.A. Tech. Bul. 900; see also: Francis, Bull, and Carroll, Ill. Bul. 501; Ill. Rpts. 1938–47, 1948; Ill. 24th Cattle Feeders' Rpt.; Branaman, Hankins, and Alexander, Mich. and U.S.D.A., Amer. Soc. Anim. Prod., Proc. 1936; Trowbridge, Moulton, and Haigh, Mo. Res. Bul. 30; Yields from Different Grades and Weights of Steer Carcasses, Wilson and Co., 1943.

105. Bull, Olson, and Longwell, Ill. Bul. 355; Helser, Culbertson, Thomas, Nelson, et al., Iowa Rpts. 1932, 1933; Brown, Mich. Rpt. 1930–32; Foster and Miller, Mo. Res. Bul. 186; Trowbridge, Moffett, and Hazen, Mo. Bul. 310; Sackville and Sinclair, Univ. of Alberta, Canada, Col. of Agr. Bul. 25.

106. Rusk and Snapp, Ill. Rpt. 1928; Culbertson and Hammond, Iowa, mimeo. rpts.; Gerlaugh and Gay, Ohio Bimo. Bul. 179; see also: Dyer and Weaver, Mo. Bul. 646.

107. Stanley and Scott, Ariz. Buls. 108, 116; Maynard, Colo. Press. Bul. 65; Maynard and Osland, Colo. Press Bul. 70; McCampbell and Horlacher, Kan. Cir. 105; Culbertson et al., Iowa, mimeo. rpt.; Vaughan, Minn. Bul. 237; Trowbridge and Moffett, Mo. Bul. 314; Dyer et al., Mo. Buls. 535, 556; Gramlich and Thalman, Nebr. Bul. 252; Loeffel, Nebr. Quarterly, 2, 1953, No. 2; Bohstedt, Ohio Bimo. Bul. 129; Bohstedt, Bell, and Gerlaugh, Ohio Spec. Cir. 10; Sackville and Sinclair, Univ. of Alberta, Canada, Col.

Agr. Bul. 25 and mimeo. rpt.; Quayle and Paules, Wyo. Bul. 308.
108. Hart, Guilbert, and Cole, Cal. Bul. 645; Snapp and Bull, Ill. Bul. 508; Snapp, Beef Cattle, 4th Ed., pp. 242–246.
109. Hart, Guilbert, and Cole, Cal. Bul. 645; Andrews, Beeson, and Dinusson, Ind., mimeo. rpt.; Wilson and Curtis, Iowa Buls. 24, 33; Gramlich and Thalman, Nebr. Bul. 252.
110. Vaughan, Minn. Bul. 237.
111. Klosterman, Kunkle, Gerlaugh, and Cahill, Ohio, Jour. Anim. Sci., 13, 1954, pp. 817–825; Chambers, Whatley, Darlow, and Stephens, Okla. Misc. Pub. MP-31; Bogart and Blackwell, Ore. Bul. 488; Bogart, Ore. Tech. Bul. 26.
112. Stanley, Ariz. Bul. 198; Rusk and Snapp, Ill. Rpt. 1931; Johnson, Keith, and Lehrer, Id. Bul. 225; Cox and Smith, Kan. Cirs. 273, 283; Smith and Parrish, Kan. Cir. 297; Hoffman, Bogart, and Burris, Ore. Bul. 528.
113. Johnson, Id. Bul. 264; Culbertson, Shearer, and McClurg, Iowa Rpt. 1944, Part 2; Culbertson, Iowa Farm Sci. Reporter, 5, 1944, No. 3; Gerlaugh, Ohio Bimo. Bul. 135; Quayle, Wyo. Rpt. 1929; see also: Fuller, Roche, and Bohstedt, Wis. Res. Bul. 102.
114. Snell, La., mimeo. rpt.
115. Stanley and Walker, Ariz. Bul. 170; Hickman, Rinehart, and Johnson, Id. Bul. 209; McCampbell and Aicher, Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1940; Thalman, Nebr., mimeo. rpt.; Thompson and Sander, N.D. Exten. Cir. 119; Bohstedt, Bell, and Gerlaugh, Ohio Sp. Cir. 10; Potter, Withycombe, and Edwards, Ore. Bul. 276; Ore. Bul. 359; Wilson and Wright, S.D. Bul. 252; Duncan, Miller, Neel, and Ewing, Tenn. Rpt. 1947; Shaw and MacEwan, Univ. of Alberta, Canada, Sci. Agr., 12, 1932, pp. 255–261.
116. McCampbell et al., Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1934.
117. Hickman, Rinehart, and Johnson, Id. Bul. 209; Potter, Withycombe, and Edwards, Ore. Bul. 276 and information to the author; see also: Thalman, Nebr. Sta.; mimeo. rpt.
118. Bohstedt, Bell, and Gerlaugh, Ohio Spec. Cir. 10; Vaughan, Minn. Bul. 237; Peters, Minn. Bul. 274; Wilson and Wright, S.D. Bul. 252.
119. Baker, Smith, Richardson, and Cox, Kan. Cir. 320; New Mex. Rpts. 1952, 1953, 1954.
120. Taylor, Willham, and Hawkins, Okla. Bul. 262.
121. Pew, Evvard and Dunn, Iowa Bul. 271; Anderson and Marston, Kan. Cir. 130; Branaman, Mich. Spec. Bul. 280; Fuller, Bohstedt, and Roche, Wis. Buls. 410, 420; Sackville and Sinclair, Univ. of Alberta, Canada, Col. of Agr. Bul. 23; see also: Mumford, Ill. Bul. 142; Trowbridge, Moffett, and Hazen, Mo. Buls. 310, 328; Darlow et al., Okla. Bul. [illegible] and mimeo. rpt.; Jones, Jones, and Bayles, Tex. Bul. 604.
122. Trials at Alabama, Iowa, Kansas, Minnesota, Missouri, Ohio, Pennsylvania, Texas, and Utah Stations. Partially reviewed by Armsby, U.S.D.A., Bur. Anim. Indus., Bul. 108. See also: Penn. Rpt. 1906 and Penn. Buls. [illegible], 102; Ala. Bul. 163; Mo. Bul. 76; Ingle, Trans. Highl. and Agr. Soc. Scotland, 1909.
123. Waters, Mo. Bul. 76.
124. Hickman, Rinehart, and Johnson, Id. Bul. 209; Potter and Withycombe, Ore. Bul. 183; Ottawa, Canada, Expt. Farms Rpts. 1910, 1911, 1912.
125. Grimes, Ala. Rpts. 1938, 1939, 1941, 1942; Templeton, Miss. Bul. 268.
126. McDaniel and Roark, La., Jour. Anim. Sci., 15, 1956, pp. 59–63; Miss. Rpts. 1952, 1953.
127. Totusek, Gallup, and Swader, Okla. Misc. Pub. MP-43.
128. Pahnish, Prog. Agr. in Ariz., 6, 1954, No. 1.
129. Good, Ky. Bul. 242.
130. Bohstedt, Ohio Bimo. Bul. 123; Black, Howe, Jones, and Keating, U.S.D.A. Tech. Bul. 847; Day, Ontario Agr. Col., Canada, Rpt. 1907; Grisdale, Ottawa, Canada, Expt. Farms, Rpt. 1904; see also: Kincaid, Copenhaver, and McClaugherty, Va., Jour. Anim. Sci., 13, 1954, pp. 959–960.
131. Pew, Evvard, and Dunn, Iowa Bul. 182; see also: Snapp, Beef Cattle, 4th Ed., pp. 585–587.
132. Williams, Stanley, and Smith, Ariz. Bul. 110; Baird, Canada Expt. Farms, Nappan, Nova Scotia, Rpt. Supt. 1923; Canada Expt. Farms, Charlottetown, Prince Edward Island, Station, Rpt. 1923.

CHAPTER XXIX

FEED AND CARE OF BEEF CATTLE—METHODS AND COSTS OF BEEF PRODUCTION—VEAL PRODUCTION

I. The Beef Breeding Herd

1208. Importance of pasture in beef production.—Pasture is the foundation of economical beef production, for it commonly furnishes much cheaper feed than do any harvested crops. Unless the beef herd is maintained on good pasture during as large a part of the year as possible, the costs will generally be high and the profits much reduced.

It has been emphasized in Chapter XIII that the productivity of pastures can be greatly increased and the forage made much more nutritious by modern methods of pasture improvement. These include the use of high-yielding pasture mixtures, proper pasture fertilization, and efficient pasture management.

During recent years outstanding advances have been made throughout this country in the general adoption of pasture improvement practices. However, even yet many farmers do not appreciate the true productive possibilities of pasture, and they give but little attention to their pasture fields in comparison with their tilled crops.

The value and use of many different grasses and legumes for pasture have been considered in detail in Chapters XIII, XVI, and XVIII. It is there pointed out that for pasture in humid regions certain combinations of legumes and grasses are generally more productive than any single grass or legume. Such high-yielding combinations are alfalfa and timothy or bromegrass, Ladino clover and grass, and lespedeza and grass. By selecting the pasture mixture that is best adapted to the local conditions, maximum yields of nutritious forage can be obtained.

The fattening of cattle on pasture is discussed later in this chapter.

1209. Establishing a beef herd.—In establishing a beef breeding herd one should start with well-bred cows of beef type, if possible, in order to secure calves that will make economical gains, mature early, and bring a high price when marketed. A purebred bull of good quality should always be used.

Recent experiments show that under most conditions beef cattle of large or intermediate size have certain economic advantages, in comparison with "compact," or "compress" cattle.[1] The calves are larger at birth and at weaning time, and in the feed lot make more rapid gains.

When fattened, the larger animals do not reach the same degree of fatness and Federal Grade so soon as the compact animals, but on a liberal fattening ration there is no significant difference in the amounts of feed required per 100 lbs. gain to reach the same degree of fatness. However, the larger cattle are more efficient when they are fattened chiefly on roughage, with a minimum amount of concentrates.

The amount of feed required by beef cows of the different sizes is approximately proportional to their liveweights. Therefore, large cows definitely need more feed than smaller ones. This is of much less importance in the case of breeding herds maintained largely on the National Forests or other public grazing land, where the grazing fees are based on the number of cows, without regard to their size.

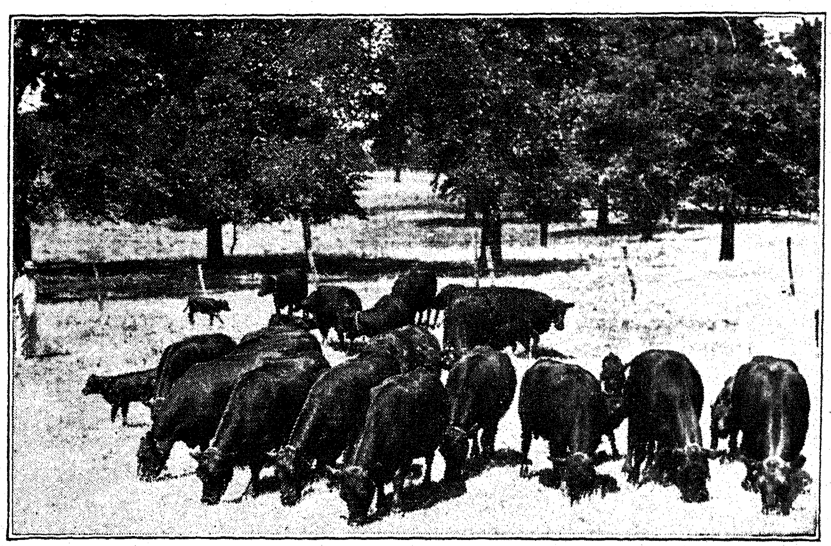
The greater amount of feed eaten by the larger cows is offset by the larger size, faster gains, and greater market weights of their calves. Also the percentage calf crop raised tends to be appreciably higher for large or intermediate cows than for those of the compact

type. In addition, with compact or comprest cows there is apt to be a greater occurrence of hereditary "dwarfism" in the calves.

There are three general systems of handling beef breeding herds. These are: (1) The regular beef method; (2) "baby-beef" production; and (3) the "dual-purpose" system. In the first two systems the calves run with their dams until weaned, none of the cows being milked. Cows producing calves intended for baby beef are, however, commonly fed a little more liberally, as is pointed out later. (1242) In the dual-purpose system beef production is combined more or less with dairying. (1216)

1210. Feeding beef breeding cows.—Where cows are kept only to raise calves for beef, the cost of their keep for an entire year must be charged against the calves at weaning time. It is therefore essential that the breeding herd be maintained as cheaply as possible, yet kept in vigorous breeding condition. Only a breeder of purebred stock who wishes to keep his herd in somewhat of "show condition" as an advertisement can afford to feed much grain to his beef cows.

Cows kept solely for beef production are commonly grazed on pasture during the growing season. The suckling calves run with their dams and no additional feed is given to cows or calves. In the fall the cows can get their living chiefly from feed that might be otherwise wasted, such as stubble or stalk fields and the aftermath of meadows. With a little foresight, the amount of such cheap feed may be increased by seeding rape



A WELL-BRED BEEF HERD

The calves from well-bred beef cows make economical gains, mature early, and bring a good price when marketed.

or clover in the small grain, and rape in the corn fields. Shade should always be supplied the herd at pasture.

The winter feed and care may range from the most intensive system, where the herd is fed in barn or shed with the freedom of exercise paddocks, to the practice followed in many range districts, where the chief feed is that furnished by the winter range on which the grass has been allowed to grow up and mature.

1211. Nutrients required by beef cows.—It has been emphasized in Chapter IX that to produce thrifty, vigorous offspring the dams must receive rations which supply sufficient protein, minerals,

and vitamins. (288–292) Fortunately, much smaller quantities of these nutrients are needed for wintering beef breeding cows than for feeding dairy cows in milk. This is because beef cows usually calve in the spring and are dry during winter. They therefore need nutrients merely to maintain their own bodies and for the growth of the fetus. As we have seen in Chapter IX, the amounts of nutrients required for the development of a calf to birth are not very large. (292)

It is for this reason that beef cows can be wintered satisfactorily on roughage alone, when some legume hay is available. If only non-legume roughage is fed, there should be added to the ration 1 lb. per head daily of a protein supplement, such as soybean oil meal, cottonseed meal, or linseed meal.

Beef cows should receive sufficient feed during the winter to keep them in thrifty condition. Otherwise, they may be unable to produce strong calves and nourish them with a good flow of milk. If they go into the winter in poor flesh, because of a shortage of feed on pasture, a little grain may be needed to get them in suitable condition before calving.

Too-liberal feeding of grain is not only extravagant but also may be actually injurious. Experienced beef producers know that the best calf crop is apt to be secured from cows kept in vigorous condition on a properly-balanced ration, rather than from cows which are fat.

Under range conditions where the beef cows must get most of their winter feed from mature and weathered grass and other forage, the supply is often so scanty in amount and poor in quality that the percentage calf crop raised is very low. (1247) Under such conditions the net income can be greatly increased by supplying enough supplementary feed to keep the cows in thrifty condition.

1212. Protein; minerals; vitamins; total digestible nutrients.—There will be no shortage of protein, calcium, or vitamins if the cows receive at least 4 to 5 lbs. per head daily of well-cured legume hay, or mixed legume-grass hay supplying this amount of legume forage. The same is true when legume or legume-grass silage forms a considerable part of the ration.

In such rations there will also be no lack of phosphorus, unless the roughage has been raised on soil deficient in this mineral. When non-legume roughage is fed with 1 lb. per head daily of protein supplement, the ration will have ample phosphorus, but there may possibly be a lack of calcium, unless the roughage was grown on soil well supplied with calcium. If no legume hay is fed, it is wise to furnish about 0.1 lb. of ground limestone or other calcium supplement per head daily.

Beef cows that have been on good pasture during summer go into winter with a considerable store of vitamin A and carotene in their bodies. (1176) Therefore, unless the winter is too long, they can be wintered successfully on a ration very low in carotene, such as straw and 1 lb. per head daily of protein supplement. However, as insurance against a lack of vitamin A, it is much safer to feed, along with such roughage as straw, at least a limited amount of well-cured hay, of silage, or of good corn or sorghum fodder. This is especially important if the cows go into winter in poor condition and depleted of vitamin A, because of drouth-stricken pastures.

Beef breeding cows that are outside in the sunlight most of the day are amply protected against any lack of vitamin D.

Plenty of salt and a proper supply of water should always be furnished the cattle. If trouble is experienced from goiter, or "big neck," in new-born calves this may be prevented by supplying the cows with iodized salt during at least the latter half of the pregnancy period. (170)

The amounts of nutrients advised for beef cows are stated in the Morrison feeding standards. (Appendix Table III.) If one is in doubt as to whether the ration he intends to feed his breeding cows is adequate, he should see how the amounts of the various nutrients in the ration correspond with the standards. If necessary, a protein or mineral supplement should be provided.

In the case of mature cows the amount of total digestible nutrients may

fall slightly below the minimum in the standard, if the cows go into winter in good flesh. On such a ration, however, the animals will probably lose in weight slightly during the winter. Cows which are not yet mature should be fed a little more liberally than full-grown ones, as they need additional nutrients for growth. Cows nursing calves in winter require more feed than those which are dry, as is shown in the feeding standards. (Appendix Table III.)

1213. Wintering cows chiefly on corn or sorghum forage.—Where corn or the sorghums thrive, these premier forage crops should generally furnish much of the roughage for the breeding herd. The crop may be fed, grain and all, as silage or dry fodder, or the grain may be removed and the stover fed either as dry stover or stover silage.

Experiments have shown that corn or sorghum silage is much more economical than the dry fodder, for it is consumed with less waste and will maintain the cows in better condition.[2] Beef cows may be wintered very satisfactorily on 50 to 60 lbs. of corn or sorghum silage per head daily and 1 lb. of cottonseed meal, linseed meal, or similar protein supplement.[3] This will keep them in good condition. Even 40 lbs. per head daily of corn silage with 1 lb. of supplement maintained cows in fair condition in an Illinois test.[4] Though the cows did not carry as much flesh as many breeders would desire, their health was not injured, and they produced vigorous calves.

In another Illinois trial beef heifers were raised on only corn silage and protein supplement, and fed this ration for 4 years until they had produced two crops of calves.[5] No ill effects of any kind were observed, and the calves were strong and vigorous.

Often it is most economical to use silage in combination with hay, straw, or other dry roughage. An excellent combination is 5 lbs. or more of legume hay and 25 to 30 lbs. or more of corn or sorghum silage.[6] Another satisfactory ration is 20 to 25 lbs. of corn or sorghum silage, with what straw the cows will eat and 1 to 1.5 lbs. of protein supplement.[7] When corn or sorghum silage is fed as the only roughage or else with non-legume roughage, it is important to feed a protein supplement.[8] A calcium supplement should also be supplied, except perhaps where the soil is high in lime.

It has been shown in Chapter XVI that corn-stover silage is satisfactory as the chief feed for wintering mature beef cows. (531) If possible, good legume [illegible] should be fed with the stover silage [illegible] 1 lb. per head daily of a high-protein supplement should be supplied, along with some hay or dry fodder.

1214. Wintering on hay and other feeds.—In the alfalfa districts of the West, alfalfa hay is widely used as the chief roughage for wintering beef cows. They can be kept in excellent condition on 18 to 25 lbs. of alfalfa hay a day, but often the cost can be reduced by combining the alfalfa with some cheaper roughage, such as prairie hay, corn or sorghum fodder or stover, or straw.[9]

In Montana trials oat hay was even better than alfalfa hay as the only feed for wintering beef cows, because of the grain it contained.[10] Sweet clover hay, native bluejoint hay, and corn fodder were also satisfactory as the only feed.

Hay made from clippings of grass pastures were too low in protein to be satisfactory as the only winter feed for beef cows in Mississippi trials, and needed supplementing with 1 lb. of protein supplement per head daily.[11]

Beef cows can be wintered very satisfactorily on hay-crop silage with a limited amount of hay. As shown in Chapter XV, the relative value of hay-crop silage, in comparison with corn silage, is much greater for beef cows than for wintering calves. (439)

In the southern states temporary winter pasture crops, such as crimson clover and rye grass or small grain, can often provide much of the feed during winter.[12] (482, 583)

The wintering of beef cows entirely or chiefly on straw has been discussed in Chapter XVII. (622)

1215. Supplementing winter range.—In those range sections where the grass or other forage is not usually covered by

snow in winter, the beef herd is wintered as largely as possible on the range. The mature, weathered winter pasture is like straw in nature, being low in protein, in phosphorus, and in total digestible nutrients. In addition, it generally has but little carotene. Severe nutritive deficiencies may therefore result if cows have no other feed for too long a time, especially if they are not in good condition at the beginning of the winter period.

Commonly, only enough supplemental feed is furnished in addition to winter range, to keep the cows from running down seriously in condition. Often a supply of hay or of silage (usually in a trench silo) is kept on hand to meet shortages of feed on the range during the winter. Others supplement the winter range by feeding cottonseed cake or some other protein supplement, when necessary.

The amount and kind of supplemental feed needed in addition to winter range is entirely a local problem, as it depends on the feed available on the range. In some areas, it does not pay to supply supplemental feed under usual conditions.[13] In other districts, supplemental feeding greatly increases the percentage calf crop, reduces the death losses, and increases the weaning weights of the calves.[14]

The poor results that follow when beef cows are wintered on a scanty supply of inferior forage are shown by the fact that beef herds wintered on pine forest ranges in the southeastern states without supplemental feed often have but a 50 per cent calf crop.[12] The average weaning weight of the calves is only about 300 lbs., and there is a 5 per cent annual death loss of the cows. Under such conditions many of the cows calve only in alternate years, as they fail to breed successfully while nursing calves. Adequate nutrition of the cows would greatly raise the calving percentage, as well as increase the weaning weights of the calves and greatly reduce the death loss.

In contrast with the poor results in such "piney-woods" herds, are those secured by Missouri commercial beef producers who kept records over a period of 14 years.[15] In these records, including more than 10,000 calves, the calf crop averaged 95.5 per cent, the calves gained 1.76 lbs. a day, and the average weaning weight was 445 lbs. at 207 days of age.

The need for supplementing winter range will depend to a considerable extent on the quantity and quality of the range forage the cows have secured the previous summer. If the season has been favorable, the cows will go into winter in good flesh and with a good store of vitamin A in their bodies. They can then draw on their body reserves to some extent during winter without injury. On the other hand, in case of severe summer drouth, their bodies will be depleted, and bad results will follow unless their winter feed is adequate.

Montana trials show that when the summer feed has been good on the range and the calves are weaned by mid-October, cows may lose 50 to 125 lbs. in weight during winter and still produce normal calves.[16] In these tests cows fed 1 to 2 lbs. of cottonseed cake per head daily in winter, in addition to range pasture, maintained their weights better than did cows fed no supplement. However, the weaning weights of the calves the next season were not enough greater to cover the cost of feeding the cottonseed cake to all of the cows. A practical way to reduce the cost is to separate out the thinner and weaker cows and feed the supplement only to them.

In Oklahoma trials good results were secured when cows were fed 8 lbs. of alfalfa hay or else 2.6 lbs. of cottonseed cake per head daily to supplement winter range.[17] The cost was less, on the average, than when they were wintered on prairie hay plus 1.3 lbs. cottonseed cake.

In South Dakota experiments 8 to 10 lbs. of early-cut native hay per head daily was a better supplement to winter range than 1 lb. of 40-per-cent-protein cubes, but the same amount of late-cut native hay was much less satisfactory.[18]

1216. Feeding dual-purpose cows. —Where dual-purpose cows are kept and milked so as to secure dairy products as well as a crop of calves, the cows should

be fed the same as dairy cows and the calves should be raised much like dairy calves, except that they should be forced to rapid growth through more liberal feeding. Since most dual-purpose cows yield only a moderate amount of milk, it is especially important that they be fed strictly according to their actual production, instead of being given more concentrates than they will pay for at the milk pail.

Sometimes the "double nursing" method is followed, in which about half the cows in the herd nurse two calves each and the others, from which the calves have been taken, are milked. It is essential that all the cows nursing calves be good milkers, as otherwise the calves will not make the gains desired.

1217. The beef bull.—Under farm conditions the bull should be kept separate from the herd of cows except at the breeding season. This plan is also often followed in range herds, so that the calves will come within a certain time and so that the bulls will have an opportunity to get in good condition before the next breeding season.

A vigorous bull 3 years old or over should serve 40 to 50 cows when hand-mated, and 25 to 30 when he runs with the cows on pasture during the breeding season. On the western range the average number of cows per bull is about 25, except in rough and mountainous country, where a bull to every 15 to 20 cows is a common proportion. A yearling bull should be hand-mated to no more than 10 to 12 cows during the breeding season, and a 2-year-old to no more than 25 to 30 cows. It is not wise to allow young bulls to run with the cows on pasture during the breeding season.

The same general principles apply to the feeding and care of beef bulls as for dairy bulls. (**1155–1157**) The bull should be kept in good, thrifty condition but not fat. Previous to the breeding season he should be well fed, and concentrates should be added at other times, as needed, to keep him in proper condition. Some prefer to feed only a limited amount of silage to a bull prior to the breeding season or during it, as he may otherwise become too paunchy. (**1156**) If a bull is a "hard keeper" and requires an abnormal amount of feed to keep him in proper flesh, he should be discarded, for he cannot be expected to sire cattle which will make economical gains. The importance of using a good purebred sire has been emphasized in the previous chapter. (**1189**)

II. Raising Beef Cattle

1218. The beef calf.—Most beef producers prefer to have the calves born in the spring, because the cows can then be wintered more cheaply than when they calve in the fall. If the cows are well fed during the winter and have proper shelter, it is generally best to have them calve in the early spring or even in late winter.

Early calves, coming before the spring work starts, can be given more attention. When the cows go to pasture in the spring, the calves will be old enough to use the increased milk flow to advantage. Also, early calves can utilize summer pasturage better than late calves and will be much larger and in better condition in the fall.

Especially in the southern states, fall calves may be more profitable than spring calves, if plenty of good feed is provided during fall and winter for the cows and calves.[19] The calves will usually bring a good price as fat slaughter calves at weaning in early summer, or they can be finished for marketing at about a year of age, when the supply of well-fattened young cattle is limited.

When the calves are born on pasture, the cows usually have no difficulty in calving and need little attention. Even when they calve in winter, beef cows, except 2-year-old heifers, are not apt to need assistance at calving time, as is sometimes the case with dairy cows. This is because their calves are rather small at birth, generally weighing only 60 to 75 lbs.

Under the simplest method of beef production, the calves are not fed any grain or other concentrates while they are with their dams on pasture during the summer. Suckling calves should gain

1.25 to 1.75 lbs. or more a day, if their dams give a good flow of milk.

Arkansas studies show that the rate of gain of suckling calves depends to a considerable extent on the milk production of their dams.[20] The milk yield of 77 beef cows was determined by milking out half of the udder on one day each month and the other half the following day. The average total yield per cow was 1,498 lbs., with a range from a high of 2,458 lbs. to a low of only 312 lbs. The calves from cows that averaged more than 13 lbs. of milk a day at peak production, weighed 475 lbs. at weaning, while those from cows that produced less than 6.5 lbs. at maximum daily yield averaged only 354 lbs. These data show the importance of good milk production by the cows.

All bull calves that are not to be retained for breeding should be castrated, preferably before fly time and when from 1 to 2 months of age. Calves to be fed for the market should be dehorned, unless it is the intention to sell them as fat calves at weaning time. A good plan, where practicable, is to prevent the growth of the horns by using a caustic pencil before the calves are 3 weeks old.

Spring calves are commonly weaned in the fall by separating them from their dams. To avoid a loss of weight at this time, it is best to teach farm-raised calves to eat grain and hay before they are weaned, and then feed them well when they are taken from their mothers.

In dual-purpose herds the same methods may be used for raising the calves as in dairy herds. Though beef-type calves raised chiefly on skimmilk will not make as rapid gains to 6 months of age or be as fat as calves that nurse their dams, they will make fully as rapid and economical gains when later fattened for market.[21]

1219. Creep-feeding suckling calves.—Beef calves that are running with their mothers on good pasture need no grain, in addition to the pasture and their dams' milk, to make satisfactory growth. However, supplying grain for the calves by means of a creep is often profitable with farm-raised calves under certain conditions.

Creep-feeding is advisable in the case of purebred calves on which maximum growth is desired. Experiments have shown that it also is generally profitable, unless the pasture is much better than average, for well-bred calves that are to be sold for beef at weaning time or shortly thereafter. Fall or early winter calves should be creep-fed during the barn-feeding period.

On the other hand, creep-feeding does not pay, except when pasture is scanty, for calves to be fattened on grain for 4 or 5 months or longer, after weaning.[22] When spring calves are to be sold as feeders in the fall, it will pay to creep-feed them on good pasture only if they will probably bring a higher price per hundredweight, because they are heavier and fatter. Often men who buy calves for fattening prefer calves in only moderate condition, because such calves, if thrifty, will make the cheapest gains.

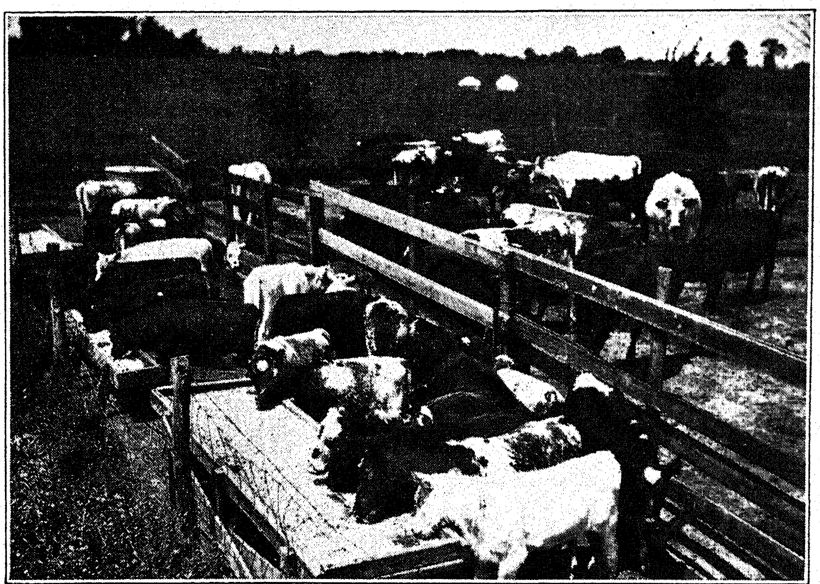
In 31 tests of creep-feeding, the calves which were creep-fed while nursing their dams gained 1.83 lbs. daily, which was 0.38 lb. more than for others not creep-fed.[23] The difference in total gain per calf for these trials, which averaged 153 days in length, was 58 lbs. The total amount of grain and other concentrates eaten per calf was 524 lbs., including that consumed by the cows while the calves were learning to eat. For each 100 lbs. of additional gain, the creep-fed calves were therefore to be charged with 903 lbs. of concentrates. In 23 tests in which the selling prices were reported, the creep-fed calves were worth $1.21 more per hundredweight at weaning time. In most of these tests the greater gains and the increased selling price paid well for the concentrates fed.

If the pasture furnishes an abundance of feed and if the cows are good milkers, creep-fed calves may not eat enough concentrates in the creep to cause much difference in rate of gain. Thus, in 4 North Carolina tests calves creep-fed on native reed and cane pasture ate an average of only 130 lbs. of concentrate mixture in 168 days and gained only 12

lbs. more per head than others not creep-fed.[24] Creep-feeding was therefore not worth while.

Because milk is rich in protein and good pasture is also fairly high in protein, merely corn or other grain, without any protein supplement, is satisfactory for creep-feeding on such pasture. Mixtures of grain and a small proportion of protein supplement are often preferred, however, as they may be slightly more palatable. In 3 Missouri tests calves creep-fed a mixture of 9 parts of shelled corn and 1 of cottonseed meal gained slightly more than others fed only shelled corn or a mixture of 2 parts corn and 1 part oats.[25] They also sold for 50 cents more per hundredweight and gave a slightly larger net return. In Oklahoma trials calves ate considerably more of a creep mixture containing molasses than others ate of a mixture without molasses.[26] There is no advantage in grinding corn or oats for suckling calves.

The creep should be built at a spot in the pasture where the calves tend to gather, as at the watering place. It is an enclosure with openings of such size that the calves can enter while the cows are kept out. At first, the cows should be allowed to enter the enclosure with the calves and eat grain, so that the calves will learn to take it. The grain can be conveniently fed in the creep by means of a covered self-feeder which will hold a supply for several days.



Beef Calves Eating Corn in a Creep on Pasture

Feeding grain by means of a creep to well-bred calves running with their dams on pasture generally pays if the calves are to be sold as fat calves at weaning time or shortly thereafter. The entrance to the creep cannot be seen in this photograph.

In Missouri tests the creep-feeding of calves that were running with their dams on pasture proved preferable to keeping the calves in a separate enclosure where they were fed grain, and turning them with the cows to nurse only twice a day.[27]

1220. Wintering calves.—Calves being wintered for later fattening must be fed primarily on roughage, in order to keep the cost of feed as low as possible. While the ration must be cheap, it is essential that the calves be kept growing thriftily. Sufficient protein, minerals, and vitamins must be provided to meet the requirements of animals of this young

age, or they will fail to make the desired growth.

The amounts of nutrients required per head daily for wintering calves and yearlings of various weights are shown in the feeding standards in Appendix Table III. Also, several example rations suited to various conditions are given in Appendix Table VII.

Many experiments have been conducted to compare various rations and to find the best methods of wintering calves which are later to be handled in different ways.[28] These experiments have shown that if the calves are to be pastured during the following summer without grain being fed in addition, the gain during the winter should not be too large, or the summer gains on pasture will be greatly reduced.

If the summer grazing will probably be good, it is generally advisable to feed calves so they will gain at least 0.75 to 1.00 lb. per head daily. This will keep them thrifty, produce good growth, and prevent them from losing much in condition. The gains will be sufficient to pay for the feed consumed during the winter, and hence the cost of the calves per 100 lbs. in the spring should be no greater than it was in the previous fall when they came off pasture.

If the cattle are to be fed grain on pasture the following season, or if they are to be fattened in dry lot in spring and summer, it is usually best to feed sufficient grain or other concentrates in winter to keep them improving in condition, or degree of fatness.

Feeding 2 lbs. or more of grain per head daily in winter may also be most profitable when the cattle are to be grazed on good pasture, without grain until midsummer, and then finished for market by full feeding grain on pasture or in dry lot. The fattening of calves throughout the winter in baby beef production is discussed later. (1242)

If the cattle will have only rather poor pasture in summer, it may be best to limit the winter feed so that they will gain only about 0.50 lb. per head daily. It is almost always advisable to secure at least this much gain during the winter, instead of feeding the calves so scantily that they grow in skeleton, but merely maintain their weights. If they do not gain during the winter, all the feed and labor is spent just for carrying them over to spring. The cost of the calves per 100 lbs. live weight in the spring will then be considerably greater than if they had been fed so as to make reasonable gains.

Many men who fatten western feeder cattle during the spring and summer, buy calves in the fall and carry them through the winter, instead of making their purchases in the spring. They find that they can generally get calves of good quality more readily in the fall, when the supply on the market is greatest. By carrying the calves through the winter, they dispose of much farm-grown roughage. Also, if the calves are fed economical rations, the cost per 100 lbs. will usually be less in the spring than the price at that time for animals of similar quality on the feeder markets.

1221. Rations for wintering calves.—In the alfalfa districts of the West, alfalfa hay is a standard ration for wintering calves or older cattle. If calves are fed all the good alfalfa hay they will clean up reasonably well, they will eat 12 to 20 lbs. of hay a day, depending on their size, and should gain about 0.75 to 1.0 lb. per head daily. When thus fed, they may waste about 2.0 to 2.5 lbs. of hay a day, but this refuse hay can often be fed to older stock being carried through the winter.

Well-cured clover hay or mixed clover-and-grass hay is about equal to alfalfa hay in value for calves. Unless hay from the grasses is cut earlier than usual, it is too low in protein to be satisfactory as the only feed. Good results are secured when good-quality timothy hay, prairie hay, or other grass hay is fed with 0.5 to 1.0 lb. per head daily of cottonseed meal or other protein supplement.

By liberal nitrogen fertilization, combined with early cutting, native hay containing a high percentage of protein was produced on a mountain meadow in recent Colorado trials.[29] Such hay would furnish plenty of protein, even for calves.

To reduce the cost, it is often ad-

visable to feed, along with alfalfa hay or other legume hay, some cheap roughage, such as corn or sorghum fodder or stover, or even straw. Calves fed 4 to 6 lbs. of alfalfa hay per day, with what straw they will eat, do not make much gain in weight, but can be carried through the winter in thrifty condition. By adding to such a ration 2 or 3 lbs. of grain per head daily, satisfactory gains can be secured.

In many sections of the country, silage from corn or the sorghums provides the cheapest roughage for calves. An excellent ration is 3 to 4 lbs. alfalfa hay and sufficient corn or sorghum silage to produce the desired gain in weight. On this amount of legume hay and 25 lbs. of corn silage, calves should gain a pound or more a day. A somewhat larger amount of sorghum silage will be needed to produce this gain. Unless at least 3 lbs. of legume hay are fed per day with corn or sorghum silage, a protein supplement should be added.

Contrary to some earlier opinions, cattle fed silage during the winter will make just as good gains on grass the following summer as others that have made similar winter gains on dry feed.

Very satisfactory gains are made when calves are wintered on a sufficient amount of corn or sorghum silage, plus 0.75 to 1.0 lb. per head daily of a protein supplement, such as cottonseed meal, soybean oil meal, or linseed meal. When thus used to balance the ration, 100 lbs. of such a supplement are worth as much as 300 lbs. of alfalfa hay.

Because of the lack of grain in hay-crop silage, on this silage it is necessary to feed calves 2 to 3 lbs. or more of grain per head daily to make as much gain as they will on corn silage with 1 lb. of protein supplement. (439)

Because wheat bran has only a medium protein content, Kansas experiments have shown that it takes 2 lbs. of bran to produce as good results as 1 lb. of cottonseed meal or cake per head daily, when used as the protein supplement in a wintering ration.[30] Other experiments by the Nebraska and Kansas Stations have shown that when protein supplements are high in price compared with farm grain, 2.0 lbs. of ground barley, oats, wheat, or grain sorghum can be used in place of 0.75 to 1.00 lb. of protein supplement, such as cottonseed cake or meal.[31] Corn is too low in protein to be used alone, but an allowance of 1.0 lb. corn and 0.75 lb. cottonseed cake, fed with silage or other suitable non-legume roughage, gives good results.

Corn-stover silage or silage made from grain-sorghum stover should not be used as the only roughage for calves, if more nutritious roughage is available. When such silage or dry corn or sorghum stover is the chief roughage, it will be necessary to feed some grain to keep the calves in good condition.

Sometimes straw is used as the only roughage for wintering calves, but this is not advisable under usual conditions, for straw is very low in total digestible nutrients and deficient in protein and carotene. When straw is thus fed, the calves should receive 1.0 lb. of protein supplement per head daily, and 0.1 lb. of ground limestone or other calcium supplement should also be supplied. At least 4 or 5 lbs. of well-cured hay had best be fed with straw, instead of using straw as the only roughage, or else it should be fed in combination with a limited amount of silage. In 3 Kansas trials wheat straw was unsatisfactory as the only roughage for calves, even when diluted molasses was sprinkled over it and protein and mineral supplements were fed.[32]

In the Southwest and in the South the calves often get most of their winter feed from winter range or pasture. In addition, a sufficient amount of protein supplement should be fed to pro[illegible] the desired gain in weight.[33] Wi[illegible] calves chiefly on pasture wher[illegible] weather permits, is usually much ch[illegible] than wintering them on harvested [illegible]

1222. Wintering yearlings [illegible] older cattle.—Yearlings and older [illegible] that are being carried through the [illegible]nter for later fattening can make even greater use of cheap roughages than can calves. Therefore, unless grain is very low in price, they should generally be wintered

on roughage alone, when they are to be grazed on pasture without grain the following summer. Of course, a small amount of a protein supplement should be added if it is needed to balance the ration. When the cattle are to be finished for a summer or early fall market by feeding them grain or other concentrates in addition to pasture, then some grain is commonly fed during the winter, especially towards spring.

Extensive experiments have been conducted at various stations and by the United States Department of Agriculture to compare various rations for wintering yearlings and older stocker cattle.[34] (Cattle being wintered for later fattening are called stockers.) The recommendations given in the Morrison feeding standards for such cattle are based upon the results of these investigations. (Appendix Table III.) Likewise, the example rations given in Appendix Table VII have been computed from the results of these studies.

While stocker cattle must be wintered cheaply, they should be fed so as to make some gain in weight. The most desirable amount of gain will depend on how they are to be handled the following summer.

Yearlings and older cattle will make good gains when wintered on a full feed of legume hay or of mixed legume-and-grass hay. Even grass hay of good quality, which has been cut reasonably early and is therefore fair in protein content, is satisfactory as the only feed for such stocker cattle. If the hay is late-cut or of poor quality, it is best to feed about 1 lb. per head daily of protein supplement. To reduce the expense somewhat, the allowance of alfalfa hay or other good hay [illegible] kept somewhat below the amount [illegible] cattle will clean up.

Except in certain alfalfa districts of [illegible] West, feeding hay alone often makes [illegible] ration unduly expensive. To reduce [illegible] cost, such cheap dry roughage as [illegible] or else corn or sorghum stover can be satisfactorily fed with at least 3 or 4 lbs. of legume hay per head daily. When most of the roughage is of low grade, it will be necessary to add 2 to 3 lbs. per head daily of grain or other concentrates to secure fair gains during the winter.

Corn or sorghum silage or silage from other suitable crops is excellent as part of the roughage, or even as the only roughage, for wintering stocker cattle. Since corn or sorghum silage is low in protein, at least 3 or 4 lbs. of legume hay per head daily should be fed with it, or else 1 lb. of protein supplement. It has been shown in Chapter XVII that a crop of corn or sorghum has a much greater feeding value for beef cattle when it is ensiled, than when it is fed as dry fodder. **(534, 554)**

In range regions where there is not too much snow in winter, winter range is commonly used as much as possible for stocker cattle. Provision should always be made for supplemental feed when the supply of feed on the range is insufficient. For this purpose hay may be stacked against time of need, or silage can be stored in a trench silo.

To supplement the mature, weathered forage, the cattle need 1 lb. or more per head daily of a high-protein supplement, such as one of the oil meals or cakes. In addition, minerals, besides salt, should be provided when needed, as advised in the preceding chapter. **(1168–1174)**

In farming districts, stalk and stubble fields can often furnish much of the feed for stocker cattle during the fall and early winter. In certain sections they are often wintered chiefly on rough land on which no cattle have been grazed in summer.

1223. Raising beef heifers and bulls.—In raising beef heifers and bulls for the breeding herd, the rations should be somewhat more liberal during the first and second winters than in the case of stocker cattle which are later to be fattened for market. It is very important that they be fed so that they will develop into vigorous animals of the proper size for their breed.

Unless at least 3 to 5 lbs. of good legume hay are fed per head daily, or an equivalent amount of legume silage, sufficient protein supplement should be added to balance the ration. Care should also be taken that there is no deficiency

of carotene or of minerals. In particular, it is wise to include in the ration some well-cured hay (legume, if possible) or some silage, in order to supply plenty of carotene. If no legume roughage is fed, a calcium supplement should be furnished, and if there is any danger of a lack of phosphorus, then bone meal or some other safe phosphorus supplement should be provided.

Corn or sorghum silage is excellent roughage for beef heifers, when fed with 1 lb. per head daily of high-protein supplement. In Kansas tests yearling beef heifers became too fat when fed all the silage they would eat, with 1 lb. of cottonseed cake per head daily.[35] Feeding 35 to 40 lbs. a day of silage with what wheat straw they cared for, plus the protein supplement, kept them in the desired condition.

In purebred herds, young cattle are commonly fed with more liberality than in commercial beef herds. The rations which have been suggested for wintering dairy heifers and young dairy bulls are well suited for use with such cattle, except that more concentrates (chiefly farm grain) will be needed in the case of animals which are being fitted for sale or show.

In commercial beef herds the heifers must be raised as economically as possible, and therefore they must be wintered almost entirely on roughage. With good legume hay and silage from corn or sorghum for roughage, little or no grain is necessary. If lower grade roughages are used, enough concentrates should be added to keep the cattle in thrifty, growing condition at all times.

Even when none of the roughage is legume, 1 lb. per head daily of such a protein supplement as cottonseed meal, soybean oil meal, or linseed meal will supply enough protein, either for calves or yearlings. Any additional amount of concentrates that is needed may consist of corn, barley, oats, or other grain. When half the roughage is legume hay, the remainder may consist of straw, corn or sorghum stover, or other rather low-grade roughage.

1224. Age to breed.—Under farm conditions beef heifers are commonly bred to calve when 24 to 36 months old. When heifers calve as 2-year-olds, they must have made excellent growth prior to calving and must have plenty of feed during the next year, or they are apt to be permanently stunted in size.

Under range conditions, unless the heifers are well developed by the time they are bred and receive sufficient feed during pregnancy, they should not calve until 3 years of age. Small 2-year-old heifers are apt to have trouble in calving, and even with careful assistance, the death loss of the heifers is appreciable and of the calves still greater.

If ranch heifers are to be bred to calve when 2 years old, they should weigh 650 to 700 lbs. when bred, and they should be fed during their second winter so that they will make satisfactory growth and be in thrifty condition at calving time.[36]

It is often advised that in order to lessen difficulty in calving, yearlings should be bred to a small-type, fine-boned bull. However, this may not make much difference in the size of the calves.[37]

In recent Oklahoma experiments heifers and cows were wintered on native range pasture plus 1 lb. of cottonseed meal pellets per head daily.[38] Heifers bred to calve first as 2-year-olds did not develop into as large cows as did those calving a year later, but produced just as many calves later, and their calves were as heavy at weaning. The cow cost per calf weaned was less for cows calving first at 2 years.

Similar results were secured in Utah and Oregon experiments.[39] In the Utah trial the cattle grazed on typical mountain range in summer and were wintered in a valley on hay and pasture. At 6 years of age, the cows calving first when 2 years old had weaned an average of 1,236 lbs. of calves per cow, in comparison with only 865 lbs. for those not calving until 3 years of age.

Differing from these results, in Kansas trials when heifers were wintered on

roughage alone and calved at 2 years of age, they failed to reach normal size.[40] Also, the average weight of their calves at weaning time was only 348 lbs. Compared with this, the average weaning weight of the calves from heifers raised similarly, but calving as 3-year-olds, was 405 lbs. Feeding the heifers a liberal allowance of grain in winter largely prevented the ill-effects of early breeding in the Kansas trials, but this method was expensive under range conditions. It was concluded that the most practical method under range and semi-range conditions was to raise heifers without grain and breed them to drop their first calves at 3 years of age.

1225. Normal growth of beef cattle.—Very few data have been published showing the weights of beef cattle of the various breeds at different ages. The following table gives the weights of females and of steers of the 3 important beef breeds in the purebred herds of the California College of Agriculture.[41] While these figures are averages for only a relatively few animals and in one herd, they are of interest in showing the rates of growth of beef cattle.

Weights of purebred beef cattle at various ages

	1 Mo. Lbs.	6 Mos. Lbs.	12 Mos. Lbs.	18 Mos. Lbs.	24 Mos. Lbs.	30 Mos. Lbs.	Mature Lbs.
Females							
Aberdeen-Angus	127	414	669	861	1,018	....	1,292
Hereford	129	401	676	855	1,031	1,097	1,453
Shorthorn	124	440	703	869	1,033	1,166	1,468
Steers							
Aberdeen-Angus	122	433	...	...	....	....	....
Hereford	132	476	850	...	....	....	....
Shorthorn	131	474	819	...	....	....	....

It will be noted that at 1 month of age there was no significant difference in weights of the heifers and the steers, but at 6 months and 12 months the steers were heavier.

In a more recent California study, the average weights of Hereford females were 300 lbs. at 122 days, 499 lbs. at 244 days, 657 lbs. at 364 days, 824 lbs. at 483 days, 912 lbs. at 608 days, 1,006 lbs. at 732 days, 1,142 lbs. at 3 years, 1,216 lbs. at 4 years, and 1,274 lbs. at 6 years.[42] In this later study Hereford bulls averaged 336 lbs. at 124 days, 605 lbs. at 248 days, 872 lbs. at 369 days, 1,077 lbs. at 487 days, 1,237 lbs. at 602 days, and 1,365 lbs. at 752 days.

III. Rations for Fattening Cattle; Fattening on Pasture

1226. Rations for fattening cattle.—The nutrient requirements of fattening cattle have been considered in detail in the preceding chapter. Information is there given on such questions as the need or advisability of feeding a protein supplement with various types of rations, the necessity of feeding a calcium or phosphorus supplement with certain rations, and the amount of grain that should be fed to various classes of cattle and under different conditions.

Example rations, adapted to various regions, are given in Appendix Table VII for the fattening of calves, yearlings, and 2-year-olds. These rations are balanced according to modern feeding standards. (Appendix Table III.)

1227. The cereal grains.—In most grain-growing regions, the cereal grains are the chief concentrates fed to beef cattle, and they are unexcelled for this purpose, when fed so as to correct their deficiencies and to take advantage of their great merits. (**680**)

All of the grains can be used satisfactorily for beef production. The choice between them will depend on the price and availability. In all sections where corn is a leading grain crop, it is commonly fed as the only grain or at least as the chief grain to fattening cattle. In the sorghum belt the grain sorghums take

the place of corn, and in the northwestern states the small grains—barley, oats, wheat, and rye—are widely used. Detailed information is given in Part II concerning the relative values of the different grains and other carbohydrate-rich feeds for beef cattle.

1228. Correcting the deficiencies of the grains.—Good legume hay largely or entirely corrects the lack of protein in the cereal grains and also supplies an abundance of calcium and of carotene. Rations consisting merely of legume hay and grain are therefore satisfactory for all classes of beef cattle. Whether or not it will pay to add a protein supplement to such a ration for fattening cattle will depend on the age of the cattle, on the kind of legume hay, and on the kind of grain, as has been pointed out in the preceding chapter. The example rations in Appendix Table VII show definitely whether a protein supplement is needed with various rations for cattle of different ages, and also the amount of supplement to be fed, if one is needed.

Rations made up of only grain and non-legume roughage are much too low in protein to be satisfactory for beef cattle. Also, such rations are apt to lack calcium, and they may be deficient in phosphorus and in carotene. Cattle fed such an unbalanced ration not only make slow and expensive gains, but also they are apt to go off feed and to suffer from digestive disturbances. Because of their poor gains, they do not become so fat as those fed balanced rations and consequently they sell for a considerably lower price.

The poor results on an unbalanced ration are shown by 8 experiments in each of which one lot of steers, 2 years old or older, was fed a ration consisting of only corn and protein-poor roughage (timothy hay, prairie hay, corn stover, or kafir stover), while another lot was fed corn and good legume hay.[43] The steers fed corn and legume hay gained 2.3 lbs. daily, on the average, and required only 689 lbs. corn and 575 lbs. hay for each 100 lbs. gain. On the other hand, those fed the unbalanced ration gained only 1.7 lbs. a day and ate 930 lbs. corn and 832 lbs. hay per 100 lbs. gain, thus requiring 36 per cent more corn and 44 per cent more hay for each 100 lbs. of gain.

It should be borne in mind that these great differences occurred with cattle that were 2 years old or older. With calves or yearlings the results from feeding unbalanced rations are even worse.

1229. Protein and other supplements.—The protein supplements most commonly used for beef cattle in this country are soybean oil meal, cottonseed meal, and linseed meal. However, several other supplements are often used, including soybeans, peanut oil meal, distillers dried grains, and corn gluten meal. Occasionally, meat scrap, tankage, or fish meal is included in supplemental mixtures for beef cattle. Wheat bran, wheat mixed feed, and wheat middlings are too low in protein to be satisfactory as the protein supplement for fattening cattle, but may be used in rations for carrying cattle through the winter.

The use and relative values for beef cattle of all these and still other protein supplements are discussed in the chapters of Part II. The quality of protein in beef cattle rations has been considered in the previous chapter. Information has also been given there concerning mixtures of protein supplements that are especially satisfactory for fattening cattle. (**1167, 1178**)

Adding an antibiotic feed supplement to a ration for fattening cattle, and the use of diethylstilbestrol have also been discussed in the preceding chapter. (**1181, 1182**).

1230. Legume hay; alfalfa meal; mixed hay.—Because of its richness in protein, calcium, and vitamins, legume hay of good quality is the best of all roughages for beef cattle. It is especially useful in keeping breeding stock in thrifty condition. Even in the case of fattening cattle, much better results are usually secured when the ration includes some legume hay than when the only roughage is grass hay or other non-legume dry forage. This is true although

sufficient protein supplement is fed to make good the lack of protein in the non-legume ration.

The results with legume hay can generally be equaled only when excellent silage, such as that from corn or sorghum, is fed as the chief roughage, and there is supplied in addition not only a sufficient amount of a good protein supplement, but also about 0.1 lb. per head daily of ground limestone or some other calcium supplement.

When the only roughage for fattening cattle is of poor quality, the gains are generally increased by adding a little alfalfa hay or alfalfa meal to the ration. As has been pointed out in Chapter II and in the preceding chapter, this not only helps supply protein, but also furnishes other factors which are needed for efficient digestion in the rumen, including trace minerals and certain unidentified factors. (45, 1178)

The effect of adding alfalfa to such a ration is well shown by 3 recent Ohio experiments.[44] Cattle full-fed corn-and-cob meal, with late-cut, poor timothy hay, enough soybean oil meal to balance the ration (1.5 lbs.), and a mineral mixture, gained an average of 1.72 lbs. per head daily. Others fed 3.5 lbs. of dehydrated alfalfa in place of the soybean oil meal gained an average of 2.07 lbs., and reached a better finish. In these trials 100 lbs. of dehydrated alfalfa was equal to 51 lbs. soybean oil meal plus 21 lbs. corn-and-cob meal and 11 lbs. hay. Because the cost of the dehydrated alfalfa per ton was as high as that of soybean oil meal, the feed cost per 100 lbs. gain was higher on the ration with the alfalfa.

In all probability the addition of a little high-quality alfalfa or other legume hay to such a ration would have had a similar effect in improving the gains and the finish of the cattle.

Good-quality mixed hay containing considerable legumes is a satisfactory roughage for beef cattle. The value per ton in comparison with legume hay will depend on the proportion of legumes and the quality of the hay.

1231. Grass hay; other non-legume dry roughages.—It has been shown in Chapter XVIII that ordinary grass hay is worth considerably less than legume hay for beef cattle. (**565**) If plenty of protein supplement and also a calcium supplement are supplied, fattening cattle full-fed on grain make satisfactory gains with high-quality grass hay for roughage. However, the value of the grass hay will be decidedly lower than that of legume hay, because so much protein supplement is needed to balance the ration.

In 3 recent Kansas trials western wheatgrass hay and intermediate wheatgrass hay were compared with sorghum silage as the only roughage for fattening yearling steers.[45] On the average the cattle gained 0.6 lb. less per head daily on the wheatgrass hay and sold for 61 cents less per hundredweight.

Fattening cattle and other beef cattle are often fed dry corn or sorghum fodder, or else shock corn. It has been emphasized in Chapter XVII that a much greater feeding value is secured per acre when a corn or sorghum crop is fed as silage than as dry fodder. (**534, 548**) As in the case of grass hay, better results are secured when fattening cattle are fed some legume hay or some silage, along with corn or sorghum fodder, than when the fodder is the only roughage.

Corn or sorghum stover is satisfactory as part of the roughage for wintering beef breeding cows or young cattle. However, stover is too low in nutrients to be very useful for fattening cattle. (**537, 551**)

Straw from the small grains is even lower than corn or sorghum stover in nutrients. It is therefore unsuited to form any considerable part of the roughage for fattening cattle. (**622**) However, if there is a shortage of better roughage, straw can replace part of the silage or hay usually fed.

Experiments reviewed in Chapter XXII show that cottonseed hulls, which are widely used for beef cattle in the South, are worth slightly more per ton than corn stover or sorghum stover, but somewhat less than good grass hay.

(826) Since cottonseed hulls do not supply carotene, they give the best results when fed along with silage or well-cured hay.

1232. Silage.—Wherever corn or the sorghums thrive, silage from these crops has proved of great value in cheapening the cost of beef production. It has been emphasized in Chapter XVII that a much greater feeding value per acre is secured when corn or sorghum is ensiled than when the crop is fed as dry fodder. (534, 548)

Experiments have shown that on well-balanced rations in which well-eared corn silage is the chief roughage, fattening cattle will make rapid gains and reach a satisfactory finish on only a moderate allowance of concentrates. (1185) Hay-crop silage may produce as good results as corn silage when fattening cattle are full-fed on grain. (439) On the other hand, when a maximum amount of roughage and a minimum of grain is fed, it will take more grain to produce satisfactory gains and finish with hay-crop silage. This is because it lacks the considerable amount of grain that there is in well-eared corn silage.

Trials at various stations have shown that it is commonly more economical to give fattening cattle twice a day all the silage they will clean up without undue waste than to limit the amount of silage.[46] Two-year-old steers full-fed on corn, legume hay, and silage will eat 30 to 40 lbs. of silage a day during the first month of fattening and gradually less as feeding progresses, until during the last month they will eat only 10 to 20 lbs. per day.

Calves and yearlings will eat considerably less silage per head daily than do 2-year-olds. Calves fattened on a liberal amount of grain will usually eat 8 to 16 lbs. of silage a day, in addition to hay, early in the fattening period and not over 6 to 8 lbs. a day towards the end.

Kentucky experiments show that if the supply of silage is used up before the fattening cattle are ready for market, they can be changed gradually to good hay as the only roughage without difficulty.[47]

Since corn silage and sorghum silage are low in protein, it is important, when such silage is fed, to balance the ration with a sufficient amount of protein supplement. (1162)

Corn or sorghum silage can be used satisfactorily as the only roughage for fattening cattle, if enough protein supplement is fed to balance the ration and if 0.1 lb. per head daily of ground limestone or other calcium supplement is also supplied. Under usual conditions, however, it is wise to feed fattening cattle at least a small amount of well-cured hay or other dry roughage in addition to silage. Cattle fed silage as the only roughage often seem to show a desire for some dry forage, and may consume more feed and make more rapid gains when it is supplied.[48]

For example, in a recent Oklahoma trial adding only 1 lb. per head daily of alfalfa hay to a ration of ground kafir grain, sorghum silage, protein supplement, and minerals for fattening calves increased the daily gain 0.23 lb. and brought a better net return.[49] Adding dehydrated alfalfa pellets had no better effect than supplying alfalfa hay.

In earlier Kansas experiments calves fed sorghum silage as the only roughage, with corn, protein supplement, and 0.1 lb. ground limestone per head daily, gained as rapidly or nearly as rapidly as did others which received alfalfa hay in addition to silage for roughage.[50]

The value of hay-crop silage, in comparison with corn silage for fattening cattle and other beef cattle, has been discussed in Chapter XV. (439) The use of silage for wintering beef breeding cows and young stock has been discussed earlier in this chapter.

1233. Fattening cattle on pasture.—It has been emphasized previously that good pastures are essential for economy in maintaining a beef breeding herd and in raising young cattle. Whether it will be more profitable to fatten cattle on pasture or to fatten them in dry lot on harvested feeds will depend on several factors.

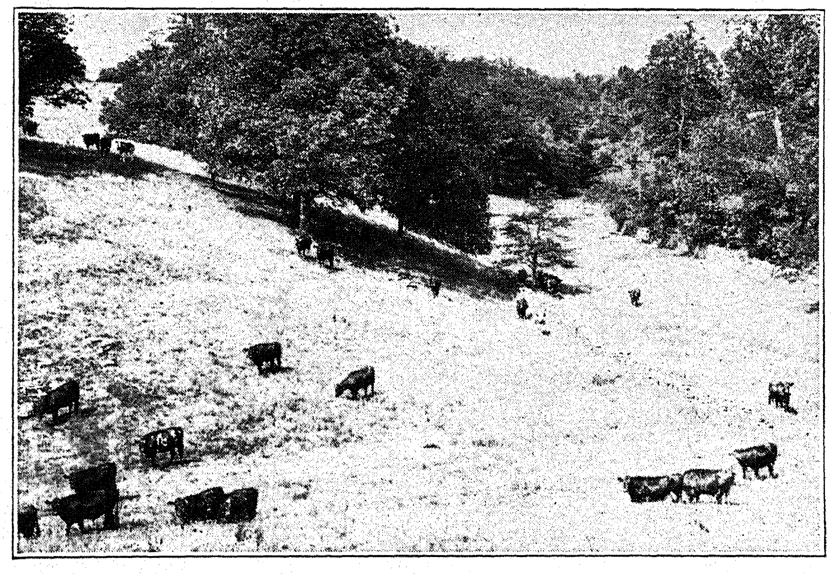
As is pointed out later in this discussion, there are certain decided ad-

vantages in finishing cattle on pasture, but also definite disadvantages. To gain much of the benefit from pasture fattening and yet avoid most of the disadvantages, pasture fattening is often combined with a relatively short finishing period in dry lot. A popular method, described later, is to graze the cattle on good pasture until midsummer, with or without the feeding of grain or other concentrates. They are then put in dry lot and full-fed on grain for 90 days or longer. (1242)

1234. Quality of beef from pasture-fattened cattle.—Experiments have proved that when cattle are equally well fattened by full-feeding grain on pasture or by fattening in dry lot, the pasture-fed cattle yield beef that is equal in palatability and tenderness to that produced by dry-lot feeding.[52] Contrary to some earlier opinions, the lean meat from cattle well fattened on pasture is no darker in color than that from cattle similarly fattened in dry lot.

When the pasture is growing luxuriantly and is high in carotene, the fat of the carcass is often a trifle yellower than in the case of cattle finished in dry lot. This yellow tinge is due to a higher carotene content of the fat, and it thus increases the vitamin value of the beef, instead of injuring it in the slightest. However, because of a prejudice in the meat trade against yellow fat, such carcasses may sell at a lower price, even though the discount is not justified.

This prejudice against yellow fat probably arose because the body fat of certain dairy breeds—Jerseys and Guernseys—is generally yellowish in color. Ex-



FATTENING CATTLE ON LAND UNSUITED FOR TILLAGE

Fattening cattle on pasture is a good way of utilizing land unsuited for tillage.

Several experiments have been conducted to compare the summer fattening of cattle in dry lot, with either full-feeding grain on pasture or with finishing the cattle in dry lot after being pastured without grain feeding for part of the season.[51] In most of these trials the feed cost of 100 lbs. gain has been decidedly less and the net return has been greater where pasture was utilized in one of these methods, than where the cattle were finished entirely in dry lot. The use of pasture in various methods of beef production is described later in this chapter.

periments indicate that if the meat is from well-fattened beef animals, a yellow tinge in the fat is not so objectionable to consumers as has been thought in the meat trade.

Cattle full-fed grain on pasture yield as high a percentage of dressed carcass as dry-lot cattle having equal finish. However, they tend to shrink a little more on shipment to market.

Cattle fattened on pasture alone, without the feeding of grain or other concentrates, generally yield carcasses of decidedly lower quality, because they are less well fattened. On account of the lack of finish, they yield a smaller percentage of dressed carcass than do well-fattened cattle, and the meat has inferior eating qualities.

1235. Advantages and disadvantages of pasture fattening.—Fattening cattle on pasture has the following advantages over dry-lot feeding: (1) Pasture gains are cheaper. This is because less grain is needed per 100 lbs. gain; because pasture is a cheaper roughage than hay or silage; and because little or no protein supplement is required. (2) Less labor is required, for the cattle need be fed only once a day, and no roughage is given. Often the grain is self-fed, still further reducing the labor. (3) The manure is well distributed on the field, and fertility is saved. (4) No shelter is required, except that shade in the pasture is highly desirable.

These advantages are more or less offset by the following disadvantages: (1) Well-fattened cattle marketed directly off pasture may sell for appreciably less per hundredweight than dry-lot-fed cattle of equal finish. (2) A farmer has less time to care for fattening cattle in summer than in winter. (3) In extremely hot weather, cattle may not make good gains, because of the heat or flies. Gains may also be checked by drouth. (4) When a permanent pasture is grazed, the manure does not benefit the fields in the regular crop rotation. (5) On pasture fields in the rotation, it may be difficult to provide water and shade.

In farming districts where much land is unsuited for tillage, the fattening of cattle on grass is common, for a maximum use is thus made of pasturage. On the other hand, on farms where there is but little untillable land, dry-lot fattening is more common, for more feed can be produced on an acre of tilled crops than on an acre of pasture.

1236. Feeding concentrates on pasture.—When cattle are fattened on pasture, no concentrates at all may be fed, a small allowance may be given during the entire pasture period, concentrates may be fed only the last few weeks, a liberal allowance may be given throughout the entire period, or the cattle may be finished in dry lot after the pasture period. In most of the experiments it has usually paid to feed some concentrates to cattle being fattened on pasture, at least during the last part of the pasture season, or else to finish them in dry lot on a full feed of grain.[53]

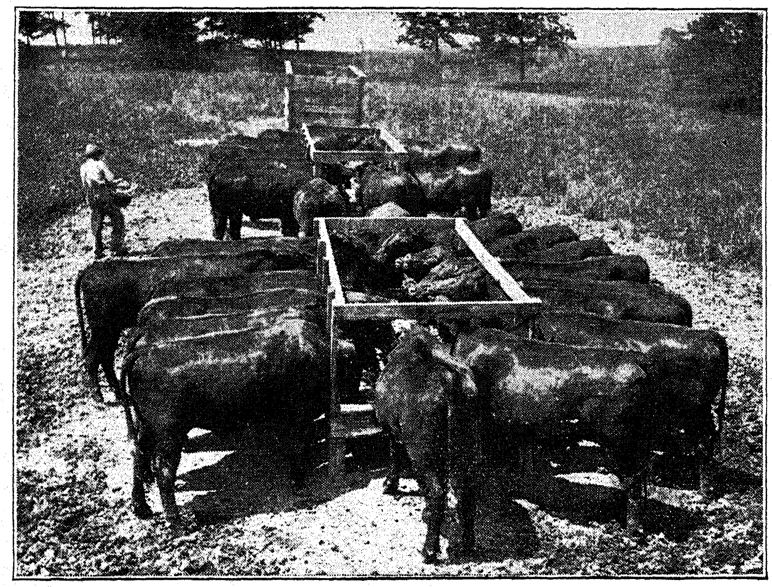
In the pasture fattening of cattle on farms, care should be taken to plan the feeding operations so as to avoid selling the cattle in late summer and fall, in competition with the large supply of grass-fat cattle from the western range. This competition may be avoided by getting cattle that are fed grain on pasture fat enough to market them before the rush of grass-fat cattle arrives. Another plan is to fatten steers of good quality sufficiently by feeding a liberal amount of grain on pasture, so that they will sell as good to choice fat steers. The prices for such cattle are usually good in late summer and early fall, due to a scanty supply.

The gains on pasture alone will commonly be cheaper than when grain is fed in addition, but the cheapness of the gains is more than offset if the cattle do not reach a good finish, and hence sell as feeders or low-grade slaughter cattle. Cattle that are 2 years old or more become much fatter on pasture alone than those that are younger, for the latter tend to grow as well as fatten. To fatten yearlings sufficiently for the large markets, it is usually necessary to feed grain in addition to pasture, or to finish them in dry lot for a short feeding period before they are marketed.

In certain districts the pasture is so nutritious that cattle 2 years old or older can be well finished on grass alone. For example, many cattle are brought from southwestern ranges for fattening without grain on the bluestem pastures of Kansas and Oklahoma. Also, many cattle are finished for market without grain on excellent bluegrass pastures, especially in certain areas from Virginia to Tennessee and Kentucky.[54]

steers being fattened on pasture will increase the gains sufficiently to be profitable, depends on the quality and stage of maturity of the pasture forage. On excellent, immature pasture, feeding a protein supplement instead of grain has generally not been profitable in several experiments.[55]

On the other hand, when grass pasture approaches maturity and is consequently lower in protein, it will pay to feed a protein supplement.[56] Also, if cattle are full-fed corn on grass pasture, containing no legumes, feeding 1 lb. of protein supplement to each 10 or 12 lbs. of corn may increase the gains enough to be profitable.[57] There is no need of a protein supplement when the forage contains a considerable proportion of legumes.



HAND-FEEDING STEERS EAR CORN ON PASTURE

It usually pays to feed some grain or other concentrates to cattle being fattened on pasture, or else to finish them in dry lot on a full feed of grain.

In the northern states the concentrate most commonly fed on pasture is corn, with perhaps a small amount of a protein supplement in addition. In the South, however, cottonseed cake or meal is often the cheapest concentrate available, and therefore an allowance of 3 to 4 lbs. per head daily is frequently fed as the only concentrate to cattle on pasture.

1237. Feeding a protein supplement with corn on pasture.—Since immature grass is rich in protein, corn and good pasture make a well-balanced ration for fattening cattle, even for calves. Whether the feeding of a protein supplement to

There is more advantage in feeding a protein supplement to cattle of high grade, that will sell near the top of the market when well finished, than to low-grade animals, which will not bring the best price, no matter how they are fed.

1238. Gains on pasture; amount eaten; area per head.—The gains of cattle fed no grain on pasture will vary widely, depending on the supply of forage throughout the season and on the nutritive value of the pasturage. On good pasture where there is an abundance of feed, yearlings should gain 1.25 to 1.50 lbs. a day for the season and 2-year-olds 1.50 to 2.00 lbs.[58] The gains are generally most rapid during the period of flush growth of pasturage in May and June and become small if the forage becomes scanty later. In the Gulf States the rate of gain is usually not over 1.0 lb. per head daily.

By digestion trials with steers on pasture, it was determined in Illinois studies that they ate as much as 35 lbs. of dry matter daily per 1,000 lbs. live weight, which made over 100 lbs. of green forage daily in some instances.[59] On 5-weeks-old bluegrass and on red clover they consumed more than twice as much forage as they needed for maintenance. Therefore, they had more than half their feed available for gain in weight.

In similar Kentucky experiments steers consumed 18.8 lbs. digestible organic matter a day on Ladino clover pasture, 11.7 lbs. on orchard grass, 10.5 lbs. on bluegrass, and only 9.0 lbs. on tall fescue.[60]

The area of pasture required per head for cattle fed no grain on pasture will range all the way from 2 acres or less per 1,000 lbs. live weight on fertile pasture in the humid districts, up to 7 to 10 acres or more on good grazing lands of the western ranges. When concentrates are fed to cattle on pasture, the area of pasture needed per head is considerably reduced.

1239. Hints on fattening cattle on pasture.—Care should always be taken in changing cattle from dry lot to pasture, especially when they are in good flesh, or else they may not continue to gain or may even shrink severely.

When cattle are turned to pasture early in the season and there is no dry grass standing over from the preceding fall, it is wise to leave them on pasture for only a short time the first day and increase the period gradually, or severe scouring may result. Because silage is laxative, if it has been fed during the winter the allowance should be reduced or entirely withdrawn as soon as the cattle are turned to pasture. If grain has been fed during the winter, it should be continued until the cattle are accustomed to grass.

If the pasture forage is very young and succulent, supplying some hay in a rack may reduce scouring the first few weeks, and increase the gains.[61]

Supplying cattle on pasture with salt, shade, and plenty of good water should never be overlooked. In regions where horn flies or other flies are serious pests, the gains of cattle on pasture are decidedly increased when they are sprayed with a wettable DDT preparation.

Cattle that have been fed a fairly liberal allowance of grain or other concentrates during the winter and that are fully half fat at the beginning of the pasture season, had best be finished in the dry lot. If they are turned to pasture, they will usually make poor and expensive gains during the first month or so.[62]

When feeder cattle are purchased early in the fall for fattening in dry lot during winter, some cheap gains can often be secured by grazing them on pasture for a few weeks before starting the dry-lot feeding. It has been mentioned in Chapter XX that cattle are sometimes turned into standing corn in the fall to harvest the crop, pigs following the cattle to get the corn not eaten by the cattle. (697)

IV. Methods and Costs of Beef Production

1240. Various methods of beef production.—Several efficient methods of beef production are followed in various parts of the United States. At one extreme is the production of heavy, fat calves, which are marketed when only 7 to 10 months of age. Next comes the production of baby beeves and fat yearlings, then the fattening of yearling

feeder cattle, and last the fattening of cattle 2 years old or more when placed on feed.

1241. Production of fat slaughter calves.—The production of fat slaughter calves is a rather recent development, brought about by the demand from consumers for light-weight carcasses that will furnish small cuts of tender beef with very little waste. These calves are often called "super" or "ultra" baby beeves, but these terms are somewhat misleading, as they imply that the carcasses of such animals are superior to baby beef. On the contrary, the beef from these calves, marketed when only 7 to 10 months old and weighing but 500 to 700 lbs., lacks the color and flavor of beef from older animals. It is lighter in color, being slightly like veal. Nevertheless, it is tender and is well liked by many people.

In this method the cows generally calve in the fall or early winter. The suckling calves are commonly creep-fed and are marketed directly off the cows from May to November, depending on their age.[63] Late calves can be weaned and fattened for 60 to 90 days.

This method is especially well adapted to the southern states, where much of the winter feed for cows and calves can come from special temporary pastures. With proper feeding, plain cows and those with some dairy blood will produce slaughter calves which will grade Choice, if bred to a good beef bull. The part dairy blood may actually be a benefit in this type of beef production, as the cows give more milk. If such calves are fattened for market when older, they will generally grade lower, because the defects in their ancestry will be apparent.

1242. Baby beef production.—Next in age at which the cattle are marketed, comes baby beef production. Under this system well-bred beef calves are so fed that they are well fattened and ready for market when 10 to 15 months of age and weighing 650 to 850 lbs. Such cattle are also classified as fat yearlings.

The carcasses provide popular-sized cuts of beef, and the meat is tender and satisfactory in taste, although not so rich in flavor as that from older cattle.[64] If the calves are well fattened, the carcasses will have a good covering of fat and the meat will have a sufficient degree of marbling. To produce meat of satisfactory quality, baby beeves need not be carried to a wasteful degree of fattening, because the lean meat is more tender than that of older animals.

Baby beef production requires, first of all, well-bred beef calves that will develop into high-grade fat cattle at an early age. Also, calves intended for baby beef must be fed liberally on grain and other concentrates. Otherwise, they will merely grow instead of fattening. This method is therefore not suited to farms where beef is produced primarily to utilize roughage. It is especially adapted to corn-belt farms where corn is cheaper than in other sections and the only pasture may be on arable, high-priced land.

Baby beef production is best suited to the farmer with a good beef herd who raises his own calves. He can be sure of having thrifty calves of the proper type for this intensive system.

In producing baby beef, the cows are fed and cared for much the same as in the more common types of beef production. They are often fed a little more liberally to ensure a good milk flow, but they must be maintained economically, or profits will be eaten up.

The calves are usually dropped in early spring and run with their dams on pasture. While on pasture, the calves are often fed grain or a concentrate mixture in a creep, at least during the latter part of the summer if pastures are short. They are then accustomed to grain at weaning time and suffer no setback. The object is to retain the "calf fat" and fatten the calves as they grow.

Calves that are in good condition in the fall at weaning time and which are full-fed on a proper ration should be ready for market from May to August, after most of the older fat cattle from the feed lots of the corn belt and other districts have been marketed. Steer calves must usually be fattened for 200 days or longer after weaning, to reach the desired finish. Heifers can generally be

made fat enough in 160 to 170 days, and bring the best price when marketed at a weight of about 750 lbs. or less. Even though pasture is available in the spring, it is best to continue fattening the calves in dry lot, instead of turning them to pasture.

When western range calves are bought on the market to be fattened for baby beef, they will not usually carry as much fat as home-raised calves. However, if they are thrifty, well-bred, and of good quality, they can be fattened on a liberal allowance of grain.[65] Care must be taken to feed a protein supplement when one is needed to balance the ration, for calves need a larger proportion of protein than do older cattle. (1163)

The amounts of feed consumed and the gains made by calves fattened for baby beef are stated in a previous article. (1195) It is there shown that calves require considerably less feed for 100 lbs. gain than older cattle, and therefore make cheaper gains.

A BEEF HERD ON A CORN BELT FARM

The calves from these well-bred cows are creep-fed on pasture and then fattened on a full feed of grain for marketing as baby beeves.

satisfactorily for baby beef by feeding them good rations, though they will not be ready for market at as early an age as calves fed liberally at all times.

Unless grain is unusually high in price in comparison with other feeds, calves being fattened for baby beef should be brought to a full feed of grain as soon as possible and should be fed liberally throughout the fattening period. When grain is extremely expensive compared to roughage, it may be most profitable to feed the calves chiefly on good roughage during the first half of the feeding period, and then finish them

1243. Finishing cattle as fat yearlings.—On farms where an important object in beef production is the utilization of pasture and harvested roughages, the finishing of cattle somewhat later as fat yearlings offers marked advantages over baby beef production. The cattle are handled according to various methods, the choice depending on local conditions. Several experiments show that the following methods all give excellent results.[66]

Where the desire is to use the maximum amount of roughage, the calves are wintered so they will gain 1.0 lb. per

head daily or slightly more. As shown previously, this will require only good roughage, such as corn or sorghum silage, with 3 to 5 lbs. of legume hay or else 1 lb. per head daily of protein supplement to balance the ration. (**1221**)

During the pasture season they are grazed, without grain feeding, on good pasture. In midsummer or towards fall, they are put in a dry lot and full-fed on grain and good roughage for 90 days or longer, until they are fat enough to meet the market demands. Under this method the cattle are marketed in late fall or early winter, before the rush comes on the market of fat older cattle from the feed lots.

In a series of New York experiments this method of handling feeder calves purchased in the fall was the most profitable.[67] These steers required about 500 lbs. less corn per head to reach approximately the same carcass grade as steers full-fed entirely in dry lot. They served as a market for about twice as much hay and corn silage, utilized 100 days of pasture during the flush pasture seasons, and made an appreciably greater net return above cost of feeder calves and feed.

In another method, steer calves of high quality are wintered similarly on roughage and then full-fed grain on pasture until fat. They should be ready for market from August to November, at the time when there is an over supply of half-fat, grass-fed cattle from the ranges and other grazing districts, but a shortage of well-finished fat cattle of good quality.

If it seems best to have the cattle ready for market somewhat earlier, the calves should receive a limited amount of grain during the winter (3 to 5 lbs. per head daily) in addition to good roughage and also a protein supplement, if the latter is needed. They can then be finished by full-feeding grain on pasture for 75 to 120 days, the length of time depending on their condition in the spring and on the degree of fatness in demand on the market. Such cattle can be classed as baby beeves.

Except perhaps when the pasturage is unusually nutritious and abundant, it is not advisable to graze the cattle without grain in summer, if they have been wintered on considerable grain with good roughage. They will then usually be too fleshy in the spring to do well on grass alone.

When the cattle are of such quality that they will grade choice to prime when finished sufficiently well, it may be best to feed them in dry lot for at least 4 to 6 weeks, before marketing. This will not only improve their actual condition slightly but will also better their appearance still more, for it will help to overcome the sunburned appearance of the coats of pasture-fed cattle. Since some buyers still have a prejudice against cattle fattened on pasture, this change in looks will usually increase the selling price.

Instead of turning the cattle on pasture in the spring, some prefer to full-feed them in dry lot during spring and summer, until they are ready for market. This may increase the selling price over pasture-fed cattle, but it requires much more labor and it increases the feed cost per 100 lbs. gain. In most of the experiments in which this method has been compared with others, it has given a lower net return than when pasture was used.

1244. Finishing cattle as 2-year-olds or older.—Where pasturage and roughage are cheap and abundant, cattle are often not finished for market until 2 years old or older. When cattle are to be fattened during their second winter, they are generally fed during the first winter on roughage alone, or roughage plus 1 lb. per head daily of protein supplement or 2 to 3 lbs. of grain. (**1221**) They are then pastured without grain feeding during the summer and put into the feed lot for fattening at the close of the pasture season.

Such yearlings can be well fattened in 100 to 160 days, if they come off the pasture in good condition. Weighing 600 to 750 lbs. when placed on feed, they are generally fat at weights of 950 to 1,100 lbs. when about 2 years old, and

meet the market demand for well-finished light-weight fat cattle.

In another method cattle are carried through their second winter chiefly on roughage, and either fattened on grass the next summer, with or without grain feeding, or else fattened in dry lot.[68] Kentucky experiments have shown that it is better to feed grain on grass than to use the same amount of grain in carrying the cattle through the previous winter, and then pasture them during the summer without grain feeding.[69]

Still other cattle are put into the feed lot as 2-year-old feeders in the fall and fattened for sale the following spring when approaching 3 years of age. The results that can be expected from fattening yearlings and 2-year-olds, in comparison with calves, are shown in the preceding chapter. (**1195**) A few cattle are still carried through 3 winters before they are fattened. However, such cattle are too heavy when fat to meet present-day demands, and therefore they have practically disappeared from the large central markets.

1245. Fattening range cows.—The purchase and fattening for the market of range cows which have been discarded on account of age or for other reasons is a hazardous undertaking. Experiments have shown that the gains made by such cows are generally very expensive.[70] Also, many prove to be so far advanced in pregnancy that they must be kept over and fattened for market after they have raised calves. In addition, there is danger of introducing brucellosis or other diseases unless such cows are carefully isolated from other breeding cattle.

1246. Fitting cattle for shows or sale.—In order to win in the show ring, both fat steers and breeding cattle must be in a high state of finish. While this degree of fatness may be detrimental to the future usefulness of bulls or cows, one cannot hope to win under present standards unless the cattle are thoroughly fat. Cattle in high condition also commonly bring a better price in a sale.

Consequently, in fitting cattle for shows or for a sale, they must be fed a very liberal amount of concentrates and a relatively small amount of roughage.[71] The economy of the ration is of relatively little importance, compared to the degree of finish that is reached.

Four to eight months are usually needed to bring cattle from thrifty breeding condition to show condition. Therefore, fitting must start early enough to accomplish the desired result.

A highly palatable concentrate mixture should be fed, in order to induce maximum consumption. For this reason, many showmen prefer mixtures containing molasses. Wheat bran is a common ingredient of mixtures for fitting cattle, due to its palatability and its mild laxative effect. Linseed meal is a favorite protein supplement, because it tends to produce a glossy coat and also because of its conditioning effect. Cattle being fitted are generally fed 3 or 4 times a day, so as to secure maximum feed consumption.

The following concentrate mixtures are recommended by Snapp for fitting cattle: [72]

1. Ground corn, 50 lbs.; crushed oats, 25 lbs.; wheat bran, 15 lbs.; and linseed meal, 10 lbs. Each feeding should be moistened with one-half pint of molasses, diluted with an equal volume of water.

2. Crushed barley, 40 lbs.; crushed oats, 25 lbs.; wheat bran, 10 lbs.; and molasses feed, 25 lbs.

3. Shelled corn, 50 lbs.; whole oats, 20 lbs.; linseed meal, 10 lbs.; and molasses feed, 20 lbs.

In order to insure maximum gains, the cattle must be comfortable. In summer they should be kept in a well-ventilated barn, except that it is desirable to turn them on good grass pasture at night. This provides exercise, as well as succulent feed. Exposure to hot sun makes their hair dry and stiff. Effective measures should be taken to control flies.

1247. Beef cattle production on the range.—About three-fourths of the beef breeding cattle in the United States are in the western states and in the great plains district from North Dakota to Texas. Here they are mostly kept under range conditions. Range beef cattle pro-

duction is also important in certain districts of Florida and other southern states.

The methods used in beef cattle production on the range differ considerably in various regions.[73] In some range sections, as in parts of Texas, the grazing land is privately owned and generally fenced. On the other hand, in the mountainous districts of the West much of the grazing is in the National Forests and on the public lands.

In the early days of the western ranges little effort was made to provide harvested feed to carry cattle through the winter. Therefore, the losses of stock by starvation were sometimes appalling in winters with heavy snowfall. Now most western ranchers have some land on which hay or other crops are raised for winter feed. In the mountain districts the cattle are commonly wintered on range land at lower elevations, adjacent to the ranch headquarters. The feeding of harvested feeds is delayed as long as possible in the autumn or winter, so the cattle will get as much of their living as they can from the winter range.

Spring calving is general in range herds, the date depending on the system of management and the climate. Occasionally, sheds are provided for shelter and the cows are bred for early spring calving, so that the calves will be heavier in the fall.

In the western mountainous regions the cattle graze in spring on the lower foothills, and then as the season advances they go to the more elevated and more rugged areas. By the end of June they are usually on this summer range, where the forage remains green and palatable until late in the season. In the fall they are brought back to the spring range.

The cattle are looked after by experienced riders or herders who see that they are kept on good grazing areas, and away from areas infested with poisonous plants. These men also provide salt at proper salting grounds and prevent the cattle from straying. The various ranchers grazing cattle in a given district usually cooperate in the spring and fall round-ups.

In the spring round-up the cattle belonging to each ranch are identified by means of the brand and are counted. The calves are branded and castrated, and also the breeding cattle are sometimes separated from the steers and yearling heifers. In the fall round-up, which takes place in September or October, the cattle to be sold are sorted out, and any calves are branded that have been dropped since the spring round-up.

Generally, the percentage calf crop is considerably smaller in range herds than under farm conditions. In the northern range districts the number of calves weaned per 100 cows bred usually does not average more than 65, and in the semi-desert range areas of the Southwest the number is even less. The calf crop is often seriously lessened by a lack of suitable feed for the cows in winter, by an inadequate supply of bulls or poor condition of the bulls, and by permitting heifers that have not been well fed to be bred to calve when only 2 years old.

The results secured at the United States Range Livestock Experiment Station in Montana show how the calf crop can be increased under good systems of range management and with proper culling of the breeding herd.[74] For a period of 18 years, including 4,753 cow years, an average of 81 calves were weaned per 100 cows in the herd. The importance of managing the grazing so as to maintain and increase the productivity of the range has been emphasized in Chapter XVIII. (385)

1248. Costs of beef production.—Cost accounting surveys conducted several years ago on corn-belt farms by the United States Department of Agriculture furnish the most extensive information that is available concerning the amounts of feed required by beef cattle, and other costs of beef production.[75] These studies, which are summarized in the following table, represent averages for 11,261 beef cows handled according to usual methods, 4,572 beef cows kept for baby beef production, 7,236 beef calves carried through the winter for later fattening, and 4,009 calves fattened for baby beef.

It will be noted that the cows were maintained almost entirely on roughage, the first group of cows being fed only 67 lbs. of grain per head annually, and the cows kept for baby beef production only 140 lbs. (Any protein supplement fed to the cows was reduced to grain equivalent.) Only 15.3 hours of man labor and 10.4 hours of horse labor per head were required per cow a year for the cows kept for ordinary beef production.

The costs of feed and labor, using local prices at any time, can be estimated from these data. After allowing credit for the value of the manure produced, the cost of feed and labor usually is 80 per cent or more of the total net cost in beef production in an enterprise of good size.

In these herds the percentage calf crop raised to weaning time was 85. This means that 85 calves were raised per 100 cows. To find the cow cost per calf raised, the estimated net cost per cow must therefore be divided by this percentage. To this must be added a charge for bull service.

In these studies data were also secured on cows in dual-purpose herds which were partially milked. Because of the credit for the milk sold, the cost per calf at weaning time was less in these herds. However, the calves were undoubtedly not so heavy or fleshy, or otherwise desirable as in the herds which were kept strictly for beef production.

1249. Cost of fattening cattle.—The cost of fattening cattle will vary widely in different sections of the country and at various times. The chief items of cost are the initial cost of the feeder cattle and the cost of the feed. Other expenses are man labor, tractor or horse labor, building and equipment charges, interest, mortality risk, veterinary services, insurance, taxes, marketing costs, and incidental expenses.

Feed and labor required for beef cows and calves

	Usual methods of beef production		Baby beef production	
	Maintaining cows per year	Wintering calves	Maintaining cows per year	Fattening calves
Feed per head				
Pasture, days	194	9	197	48
Hay, lbs.	1,900	1,218	1,940	1,150
Silage, lbs.	700	266	740	658
Straw, lbs.	660	110	500	40
Fodder, lbs.	. .	159	. .	. .
Corn or other grain, lbs.	67	482	140	2,296
Protein supplement, lbs.	. .	. .	7	141
Corn stalks, acres	1.4	0.1	2.0	0.03
Labor per head				
Man hours	15.3	8.6	16.7	12.2
Horse hours	10.4	6.8	9.6	9.1

The cost of the feed will generally form 70 to 80 per cent or more of the operating expenses, not including the initial cost of the cattle or the expenses of marketing them. It is often assumed that when cattle are full-fed on shelled corn or ear corn, the by-products of fattening operations (the manure secured and the pork produced by the pigs following the cattle) will usually pay for all farm costs other than the initial costs of the cattle and the cost of the feed.[76] However, to get this result, losses of fertilizing value in the manure must be avoided and labor cost must be reduced by efficient planning and equipment.

It must be borne in mind that when cattle are fattened in winter on a general farm, most of the labor comes at a time of the year when it might not otherwise

be utilized. Therefore much of it does not represent any real additional expense.

In an extensive survey of the fattening of beef cattle on farms in Indiana, Illinois, Iowa, Nebraska, and Missouri (including data on 34,934 cattle), the United States Department of Agriculture found that on the average the cattle weighed 786 lbs. when placed on feed, were fed for 174 days, and made daily gains of 1.63 lbs. and an average total gain of 284 lbs. during the feeding period.[77] For each 100 lbs. gain there were required 680 lbs. grain (chiefly corn), 62 lbs. commercial concentrates (chiefly protein supplements), 391 lbs. hay and other dry roughage, 863 lbs. silage, and 20 days of pasturage.

1250. Reducing the cost of beef production.—Even under the same general conditions, there is often a great difference in the cost of producing beef cattle on individual farms. For example, in a study of methods of wintering beef cows on corn-belt farms by the United States Department of Agriculture, it was found that on some farms the cost was twice as high as on others.[78] This was due largely to a failure to use cheap roughages in wintering the cows. Many farmers were overfeeding their cows and hence wasting feed, without securing any better calves. One of the greatest wastes was found to be the feeding of unhusked corn fodder, in place of husking out the corn for other stock and feeding the cows the stover, after cutting or shredding it.

Pasture improvement and fertilization and the utilization of pasture over a long season are essential to produce beef at minimum expense. Full use should always be made of the cheap feed furnished by grazing on stalk and stubble fields and the aftermath of meadows.

Another important factor in reducing the cost of producing beef cattle is to build up, by selection, a herd of cows which are all regular breeders and satisfactory mothers, producing plenty of milk for their calves.

Much labor can be saved and the amount of hard work greatly reduced by efficient equipment and good planning in the storage and handling of feed and in stabling arrangements. For example, in Illinois studies on corn-belt farms, the amount of time spent in feeding, per ton of feed, ranged from 35 minutes to a low of less than 10 minutes per ton.[79] The travel per ton of feed varied from a high of 11,300 ft. down to 273 ft. for the most efficient arrangements.

From these and other studies the following ways in which time and labor can be saved were emphasized:

1. Haul silage in carts or in cars moved over rails, instead of carrying it in baskets.
2. Use self-feeders built into the mow floor for feeding chopped hay.
3. Use self-feeders instead of feeding by hand.
4. Use blower pipe to move feed from grinder to feeder.
5. Have feedlots near the feed-storage buildings.
6. Provide hopper-bottom bins, drag conveyors, and elevators in cribs and granaries.
7. Provide better chore routes for trucks and wagons by replanning barnyards and fences.

By use of a hydraulic manure loader, the most disagreeable work can be largely avoided and much time can be saved.

V. Counsel in the Feed Lot

1251. Cattle fattening requires business judgment.—Even more than in other types of livestock farming, the fattening of purchased feeder cattle requires sound business judgment, or the venture is apt to result in loss. This is because it is a much more speculative enterprise than most ventures in animal husbandry. To secure good profits it is therefore especially necessary that the several factors which make for success be kept clearly in mind.

Before buying feeder cattle, one should estimate the quantity of feed on hand and determine how many and what class of cattle he had best buy to consume the feed. From a study of market reports he can estimate how much his feeders will cost, including the cost of

getting them to his feed lot. He can figure out approximately how much the gains will cost him, by using data like that given in this and the preceding chapter. He can then estimate the necessary selling price he must secure to break even, considering the marketing costs. If the outlook for a profit does not seem reasonably good, it is usually best not to buy just at that time.

The kind of feeder cattle should always be chosen which will probably offer the best opportunity for profit at the particular time. The summaries presented previously show the results that can be expected from various grades of feeders and from calves, yearlings, and 2-year-olds. (**1195–1197**) It is an old adage among stockmen that "cattle bought right are more than half sold." A man may be a skillful feeder and lose money year after year because of poor judgment in buying.

The beginner should hire an experienced cattleman to purchase animals that will best suit his needs, or deal with a reliable commission firm that is acquainted with his conditions. If choice feeders are commanding a high premium in the market over lower grades, and it does not seem probable that the premium will be correspondingly large for the cattle of better quality when they are fattened, a lower grade had better be purchased.

By following the various market reports for preceding years one can tell approximately at what time of year his cattle can be marketed to greatest advantage. They should then be fed so as to be finished at that time. It has been emphasized in the previous chapter that the cattle should be fattened only enough to return the greatest profit under the particular market conditions. (**1198**) It is much more important to secure a good net return than it is to "top the market."

When the cattle are ready for market, it is usually not advisable to hold them for better prices, unless they continue to make gains at a reasonable cost. The extra feed consumed by finished cattle will soon more than offset any ordinary increase in price that may be obtained. When the cattle are almost finished, the owner should watch the market reports and find out from his commission firm what they consider the best date for shipment.

1252. Rations for fattening cattle.—The experiments reviewed in the preceding chapter show that much greater profits are secured when fattening cattle are fed properly-balanced rations. Whenever there is any question as to whether a ration is balanced, it will take but a short time to compute the approximate amounts of dry matter, digestible protein, and total digestible nutrients it contains, and see how closely the ration meets the recommendations of modern feeding standards (Appendix Table III). The time it takes to work out suitable and economical balanced rations is commonly the most profitably spent of all the year. Example rations suited to various conditions are given in Appendix Table VII.

To determine which of the several available feeds are actually the most economical, one should refer to the detailed discussions of the various feeds which are given in the chapters of Part II of this volume. Definite information is there presented concerning the relative value for beef cattle of all the more important feeds.

1253. Equipment for feeding cattle.—It has been emphasized previously that much labor can be saved and the amount of hard work reduced by efficient storage and handling of feed, good stabling arrangements, and the use of a hydraulic manure loader in cleaning stables and yards. (**1250**)

The shelter requirements for beef cattle under various climatic conditions have been discussed in the previous chapter. (**1204**) Where the soil and climate are such that the feed lots often become seas of mud in winter or early spring, paving them with concrete is an economy. Not only do the steers make larger and more economical gains, but also much loss of manure is prevented. (**1206**)

Cattle of the same age, or at least those of equal size and strength, should

be fed in the same lot. From 2.5 to 3 feet of feed racks or bunks should be provided per steer, so there will not be undue crowding at meal time. Some feeders use combination feed racks for grain and roughage, while others prefer a separate rack for hay and a bunk or flat manger for silage and grain. Feed racks and bunks should always be cleaned after each feeding. Salt and fresh water should always be provided beef cattle. (1169, 1181)

1254. Getting cattle on feed.—Cattle that are not accustomed to grain or other concentrates must be started on feed gradually, or serious digestive trouble may result. When feeder cattle are first brought to the feed lot, it is best to restrict the amount of hay or other roughage slightly for a day or so, until they have recovered from the effects of their trip.

They should then be started on grain. A safe plan is to feed calves not more than 1 lb. of grain per head at the first feed, or 2 lbs. for the day. Older cattle may be started on a little more grain. The allowance may be gradually increased at the rate of about one-half pound per head daily or less, care being taken not to increase the amount unless the cattle are eager for each feed and clean up the grain properly.

If they wish to get cattle on a full feed of grain as soon as possible, experienced men may increase the allowance of grain as much as 1 lb. per head daily. When cattle are approaching a full feed, the increase should be very gradual.

If a protein supplement is to be fed to balance the ration, it is best to feed no more than one-quarter to one-half pound per head daily at first and then gradually increase the amount at the rate of one-quarter pound per head daily until the full amount needed to balance the ration is supplied.

1255. Frequency and order of feeding.—Most cattlemen feed concentrates and roughage twice a day to fattening cattle not on pasture. Often cattle being fitted for shows are fed grain more frequently, so as to induce them to consume a larger amount.

The feeding should always be at the same time each day. The cattle should not be disturbed until after daylight, and they should have time to clean up the evening feed before dark. Usually, the concentrates are fed first and then the silage is put in the feed bunk, if this excellent feed is being used. Hay or other dry roughage is fed in suitable racks, also twice daily as a rule. However, if two kinds of roughage are fed, sometimes one is fed in the morning and the other at the evening feed. In this case, the less palatable roughage should be fed in the morning. So that each animal can get its share of protein supplement, such as linseed meal or cottonseed meal, it should be mixed with the grain or else distributed over the silage.

Though cattle being fattened in dry lot are usually fed twice a day, in Tennessee and Wisconsin trials the gains were as rapid when both grain and roughage were fed only once a day.[80]

When cattle are given grain or other concentrates on pasture, they are commonly fed but once a day. This is largely as a matter of convenience, for they may be grazing on a pasture at some distance from the farmstead.

1256. The eye of the master fattens his cattle.—There is so much truth in the old adage, "The eye of the master fattens his cattle," that every stockman should bear it in mind. Being versed in the science of stock feeding is not enough for success. To secure the greatest profits, not only must one feed his stock economical and well-balanced rations, but also he must have the watchful eye and good judgment of a true stockman. The best results are obtained only when the cattle are fed at regular hours, and when the attendant is quiet and kind at all times, so that the animals trust rather than fear him.

Experience counts for much in stock feeding. Many an experienced stockman can carry steers through the fattening period without getting them once "off feed," but yet cannot well describe to others just why he is so successful. In general, when steers are to be full-fed on grain, they should be supplied all they

will readily consume at each feeding, after they have been gradually brought onto feed. Any feed left in the feed bunk or manger should be cleaned out before the next feeding, for it will not usually be eaten by the cattle afterwards, but will spoil and contaminate the fresh feed put in later.

Scouring, the bane of the stock feeder, should be carefully avoided, since in a single day it may cut off a week's gain. This trouble is generally brought on by overfeeding, by unwholesome food, or by a faulty ration. Overfeeding comes from a desire of the attendant to push his cattle to better gains, or from carelessness and irregularity in measuring out the feed supply. When cattle are fattened on alfalfa hay and barley or wheat grain, care must be taken to avoid trouble from bloat. (**49**)

The droppings of the steers are an excellent index of the progress of fattening. While they should never be hard, they should still be thick enough to "pile up" and have that oily appearance which indicates a thrifty condition. There is an odor from the droppings of thrifty, well-fed steers known and quickly recognized by every good feeder. Thin droppings and those with a sour smell indicate something is wrong in the feed yard.

1257. Pigs following fattening cattle.—When fattening cattle are fed ear corn, shelled corn, or corn silage, pigs should be kept with them to utilize the unchewed and undigested corn in the droppings. Frequently, the margin in cattle fattening is so narrow that the gains made by the pigs form the larger part of any profit from the feeding operation. When cattle are fattened on such a ration as ground grain and hay, without corn silage, or on cottonseed meal and cottonseed hulls or hay, there is no need of having pigs in the feed lot, for they could not secure much of any waste feed.

The number of pigs per steer varies with the kind of feed and the age of the cattle being fed. For cattle full-fed on the common corn-belt ration of shelled corn, corn silage, legume hay, and a small amount of protein supplement, 1 pig will be needed for approximately 1 to 2 steers in the case of 2-year-olds, 1 pig to 2 steers with yearlings, and 1 pig to each 3 calves. When ear corn or snapped corn is fed, the wastage of corn by the steers is greater, and twice as many pigs may be required. In the case of ground corn or corn-and-cob meal, only one-half to one-third as many pigs are needed as with shelled corn.

The best pigs for following cattle weigh from 50 to 150 lbs., and when they become fat they should be replaced. Pigs following steers should be fed 0.2 to 0.3 lb. per head daily of tankage or similar protein supplement to balance the ration. Any extra grain given the pigs to ensure their making satisfactory gains should be fed in adjacent separate pens before the cattle are fed, so that the pigs will not crowd around the feed troughs or under the truck or wagon while the cattle are being fed.

In Iowa experiments the amount of feed saved by pigs from the droppings of cattle full-fed on shelled corn was estimated by feeding similar pigs separately.[81] It was found that for 53 separate lots of fattening cattle, the average pig, following 1.9 steers, recovered the equivalent of 312 lbs. of corn during an average feeding period of 120 days. On the average, 4.7 per cent of the cost of the feed given to the steers was saved by the pigs.

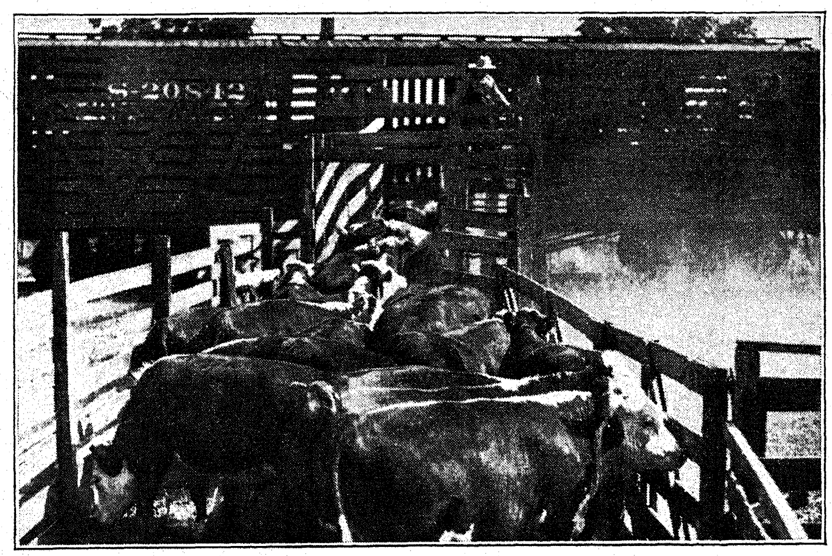
From a study of the results of many experiments, Snapp estimated that, on the average, pigs following cattle fed shelled corn would make approximately the following amounts of gain per bushel of corn fed the cattle:[82] Two-year-old cattle, 1.58 lbs.; yearlings, 1.01 lbs.; calves, 0.76 lb.

1258. Shipping; shrinkage; dressing percentage.—The shrinkage of fat cattle during shipment can be reduced to a minimum by proper handling before shipment and by care in loading. The cattle should be handled quietly and should never be driven faster than a slow walk. If they are hurried, they will begin to scour and will shrink unduly. The car should be cleaned, if necessary, and to prevent slipping should be bedded with sand, containing no stones. In cold

weather this should be covered with straw. If different kinds of livestock are put in the car, they should be separated securely. Any bulls should be tied safely in car or truck, so they cannot injure other animals.

The livestock industry suffers a heavy loss, estimated at over $27,000,000 a year, from bruised animals, because the bruises must be trimmed out of the carcasses.[83] Important ways of reducing this loss are the points that have been supplied at the last feeding should be reduced, since cattle travel better when not too full.

Silage-fed cattle show a larger gross shrinkage but usually fill so well at market that the net shrinkage is even lower than with cattle fed no silage. Cattle that have come off succulent pasture usually shrink more than those which have been fattened in dry lot. Cattle fattened on wet beet pulp shrink more than any other class.



LOADING FAT CATTLE FOR SHIPMENT

The shrinkage of fat cattle on shipment to market can be reduced by proper handling before shipment and by care in loading.

mentioned and also the following: Dehorning; removing projecting nails, splinters, or broken boards from fences, racks, trucks, and cars; keeping old machinery out of feed lots; using good loading chutes, which are not too steep; loading slowly; and using canvas slappers instead of whips, canes, or sticks.

There is probably little or no advantage in making decided changes in the ration previous to shipment, even if the cattle have been receiving silage. If very laxative feeds have been used during fattening, such as pea-green alfalfa hay, it is wise to reduce the amount the day before shipment. Also, the amounts

Some have advised changing cattle that have been full-fed a laxative ration, such as grain with silage and good legume hay, to such a ration as grass hay and a small amount of oats a day or two before shipment. This may apparently reduce the shrinkage to market, but the reduction is usually merely the result of the previous loss in weight when the change was made in the ration.

It is a mistake to withhold salt from the cattle for a few days, and then salt them liberally just before shipment, so that they will take on a large fill of water at the stockyards. If this is done, the cattle will generally scour in transit, shrink

heavily, and arrive in poor shape. Buyers both of fat cattle and of feeder cattle can recognize animals which have taken on an abnormal fill, and they discriminate against them by offering a lower price per hundredweight.

When cattle reach the market just before being sold, the fill is small, but when they arrive about daylight of the sale day, or the afternoon of the day before, they generally take a good fill.

The shrinkage between the loading weights and the sale weights at the stockyards, after feed and water, of either feeder cattle or fat cattle in transit 36 hours or less is usually about 3 to 5 per cent; when in transit 70 hours or over, the shrinkage is 5 to 6 per cent of their live weight and sometimes more.[84] In addition, there will be a slight shrinkage in weight from the feed lot to the loading station.

Well-fattened cattle shrink a smaller percentage of their live weight than those that are not so fat. For example, the percentage shrink of feeder cattle is higher than for the same animals shipped the same distance after fattening. Calves that are well-fattened have no higher percentage shrinkage than older fat animals. In 10 comparisons steer calves shrank 3.2 per cent on the average; yearling steers, 3.5 per cent; and 2-year-olds, 3.6 per cent.[85]

Good to choice fat steers will range from 56 to 59 per cent in dressing percentage, and show steers, which are of extra good type and in high condition, will usually dress 59 to 63 per cent. Fat cows dress about 56 per cent, and canners from 35 to 43 per cent.

VI. Veal Production

1259. Veal production.—Only dairy calves are commonly fattened for veal, because a better return is secured from beef calves when they are raised for beef. For the highest grade of veal, calves must be liberally fed for several weeks on whole milk as the chief or only feed. Otherwise, the carcasses may not have a sufficient degree of fatness, combined with the desired light-colored flesh and white fat.

In a recent Wisconsin trial, the addition of an iron and copper supplement to the milk to prevent possible anemia, was detrimental, because it produced pinker flesh, instead of the desired light color.[86]

Calves fattened for veal on whole milk alone for 30 to 50 days require 9 to 10 lbs. of milk per pound of gain in live weight.[87] Holstein calves fed liberally on whole milk should gain 1.8 to 2.0 lbs. a day, and calves of the smaller breeds somewhat less.

In the intensive market-milk districts, dairy calves are commonly sold for veal when only a few days old. While they would bring a considerably higher price per hundredweight if carried on milk for a longer time, this is not profitable unless the price of milk is low.[88]

Most of the well-finished veal is therefore produced in less intensive dairy regions, where a lower price is received for whole milk. Calves weighing less than 140 lbs. usually bring a decidedly lower price per hundredweight than those carried to this weight.

The gains are usually more rapid when a calf nurses a cow than if it is fed a liberal amount of whole milk. However, a recent Tennessee trial with identical twin heifers indicates that a cow which nurses her calf for several weeks produces less total milk during the lactation, even if she is stripped out after the calf nurses.[89] This lessened milk yield, which averaged 317 lbs. in this study, should therefore be included in the cost of producing the well-fattened veal calf.

Sometimes calves being fed for veal are changed from whole milk to skimmilk at 2 to 3 weeks of age and then fed skimmilk with a grain mixture and good hay, much the same as in the skimmilk-method of raising calves. Though calves thus fed make good growth, they do not lay on much fat and therefore bring a much lower price per hundredweight than calves fed plenty of whole milk.[90]

Illinois and Ohio trials indicate that the finish of veal calves fed skimmilk or reconstituted skimmilk can be improved considerably by adding a special milk-fat substitute to the skimmilk.[91] Also, the

rate of gain is generally increased by adding an antibiotic feed supplement to the skimmilk.[92] (1121)

For feeding with skimmilk, such a mixture as one-half corn and one-half oats produces as good results as a more complex mixture higher in protein.[93] (1131)

QUESTIONS

1. Why is pasture the foundation of economical beef production?
2. Describe the usual methods of feeding beef breeding cows throughout the year, when they are kept solely for beef production.
3. Discuss the nutrient requirements of beef cows.
4. State 3 satisfactory rations for wintering beef cows.
5. How are beef cows wintered in range areas?
6. How does the feeding of dual-purpose cows differ from that of cows kept solely for raising calves for beef?
7. What are the most important points in the feed and care of the beef bull?
8. What are the advantages of having beef calves born in the spring?
9. Under what conditions is it profitable to creep-feed suckling calves?
10. Discuss the feeding of beef calves being carried over the winter, stating the amount of gain that should be made under various conditions.
11. What sort of rations should be used for wintering yearlings and older stocker cattle?
12. Discuss the raising of beef heifers, including the age at which they should drop their first calves.
13. State a typical ration fed to fattening calves in your region.
14. What quality of beef is secured from pasture-fattened cattle?
15. Give the advantages and disadvantages of pasture fattening.
16. Discuss the feeding of concentrates to cattle being fattened on pasture.
17. Should a protein supplement be fed with corn on pasture?
18. About how many pounds of gain do cattle make on pasture alone during the grazing season in your region?
19. Describe the following methods of beef production: (a) Production of heavy fat calves; (b) production of baby beef; (c) production of fat yearlings; (d) fattening cattle 2 years old or older; (e) fattening old range cows.
20. Describe a method of feeding and management common on the western ranges.
21. Discuss briefly the feed and labor required for beef cows and calves.
22. Why is good business judgment especially necessary in the fattening of purchased feeder cattle?
23. What equipment is necessary for fattening cattle?
24. Describe the method of getting fattening cattle on feed.
25. Discuss the frequency and order of feeding for fattening cattle.
26. Summarize the chief facts concerning the use of pigs to follow fattening cattle.
27. About how much do cattle shrink that are 36 hours or less in transit to market? How can shrinkage be reduced to a minimum?
28. Discuss the production of veal.

REFERENCES

1. Ingalls and Stonaker, Colo. Farm and Home Res., 1, 1950, No. 2; Stonaker, Hazaleus, and Wheeler, Colo., Jour. Anim. Sci., 11, 1952, pp. 17–25; Stonaker, Ingalls, and Wheeler, Colo., Jour. Anim. Sci., 11, 1952, pp. 26–33; Weber, Mackintosh, Good, and Smith, Kan. Cir. 273; Knox, Watkins, Koger, and Valentine, New Mex. Bul. 359; New Mex. Rpt. 64; Chambers, Whatley, and Stephens, Okla. Misc. Pub. MP-34; Willey et al., Texas, Jour. Anim. Sci., 10, 1951, pp. 195–202; Wyo. Rpt. 59; Am. Hereford Jour., Mar. 15, 1952.
2. Mumford, Ill. Bul. 111; McCampbell, Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1920; Sheets and Tuckwiller, West Va. Bul. 190; U.S.D.A. Bul. 1024.
3. Tomhave and Severson, Penn. Buls. 138, 150, 170
4. Rusk, Ill., information to the author.
5. Snapp, Ill., Beef Cattle, 4th Ed., p. 153.
6. McCampbell, Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1922, 1924; Gerlaugh, Ohio Spec. Cir. 10.
7. Sheets and Tuckwiller, West Va. Bul. 190; U.S.D.A. Bul. 1024.
8. McCampbell et al., Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1921; Templeton, Miss. Rpt. 1928; Gerlaugh, Ohio Spec. Cir. 10; Kyzer and Clyburn, S.C. Rpt. 1931.
9. Vinke and Dickson, Mont. Bul. 275; Hulme, Utah Bul. 237.
10. Vinke and Dickson, Mont. Bul. 275.
11. Patterson, Miss. Bul. 506.
12. Campbell and Cassady, La. Bul. 452; see also: Ga. Coastal Plain Buls. 44, 46, 49; Southwell, Ga. Rpt. 1951.
13. Stanley, Ariz. Tech. Bul. 79; see also: Klosterman, Langford, and Douglas, N.D. Bul. 371.
14. Guilbert and Rochford, Cal. Cir. 115, Cal. Rpt. 1940; Snell et al., La. Bul. 387; Lantow and Snell, New Mex. Bul. 144; Lantow, New Mex. Bul. 202; Foster, New Mex. Rpt. 63; Biswell and Hostetler, N.C., Jour. Anim.

Sci., 4, 1945, pp. 387–394; Ore. Bul. 461; Whitehair and Gallup, Okla. Tech. Bul. T-53; S.D. Rpt. 1944.
15. Cited by Kyd, Ind. Mimeo. Rpt. A.H. 49
16. Black, Quesenberry, and Baker, U.S.D.A. Tech. Bul. 603; Mont. Rpt. 1936.
17. Nelson et al., Okla. Bul. B-418.
18. Johnson, Moxon, and Smith, S.D. Bul. 419.
19. Craine and Riley, La. Rpt. 1949; Means, Miss. Bul. 328; Acker, Pope, Humphrey, and Stephens, Okla. Misc. Pub. MP-34; Tenn. Rpt. 64; see also: King, Ind. Rpts. 1938, 1939.
20. Gifford, Ark. Bul. 531; see also: Rollins and Guilbert, Cal., Jour. Anim. Sci., 13, 1954, pp. 517–527.
21. Cattrell, Haney, and Elling, Kan. Bul. 113; Norton, Mich. Bul. 261.
22. McCraine et al., La. Rpts. 1943, 1944, 1946; Nelson, Bratcher, Humphrey, and MacVicar, Okla. Tech. Bul. B-462; Johnson and Fenn, S.D. Rpt. 1940; Duncan, Hobbs and Ewing, Tenn. Rpt. 1949.
23. Osland and Morton, Colo. Press Bul. 87; Ga. Coastal Plain Bul. 42; Bray, La. Bul. 249; Taylor, Willham, and Hawkins, Okla. Bul. 235; Nelson, Bratcher, Humphrey, and MacVicar, Okla. Tech. Bul. B-462; Johnson and Fenn, S.D. Bul. 373; Duncan, Hobbs, and Ewing, Tenn. Rpt. 1948; Jones and Jones, Tex. Bul. 470; Black and Trowbridge, U.S.D.A. Tech. Bul. 208; McComas and Wilson, U.S.D.A. Tech. Bul. 664; see also: Means, Miss. Rpt. 1932; Kyzer and Jones, S.C. Rpts. 1940, 1943; Anderson, Cunningham, Heishman, and Livesay, West Va. Bul. 357, Part 1.
24. Foster, Biswell, and Hostetler, N.C. Bul. 355; see also: Stanley, Ariz. Bul. 79; McCraine, Bray, and Francioni, La. Rpts. 1943, 1944.
25. Black and Trowbridge, U.S.D.A. Tech. Bul. 397.
26. Nelson, Bratcher, Humphrey, and MacVicar, Okla. Tech. Bul. B-462.
27. Black and Trowbridge, U.S.D.A. Tech. Bul. 208; Trowbridge et al., Mo. Buls. 244, 256, 272, 285.
28. Hilston and Gifford, Ark. Bul. 463; Ruby, Ray, and Mabry, Ark. Bul. 515; Connell, Wheeler, and Tom, Colo., Jour. Anim. Sci., 6, 1947, p. 493; Baker, Fla. Rpt. 1952; Ga. Coastal Plain Bul. 44; Johnson, Rinehart, and Hickman, Id. Buls. 229, 239, 244, 255, 269; Rusk and Snapp, Ill. Rpt. 1930; Ill. Rpt. 1938–47; Pickett and Smith, Kan. Cir. 250; Kessler, Aicher, and Weber, Kan. Cir. 260; Smith, Good, and Cox, Kan. Cirs. 273, 297; Smith et al., Kan. Cir. 308; Duitsman and Kessler, Kan. Cir. 322; Branaman and Harrison, Mich. Quar. Buls., 28, 1946, No. 4; 29, 1947, No. 4; Trowbridge and Moffett, Mo. Buls. 285, 300; Dyer, Guyer, and Weaver, Mo. Bul. 535; Templeton, Miss. Bul. 268; Arnett, McChord, and Tretsven, Mont. Bul. 176; Arnett, Baker, and Vinke, Mont. Bul. 188; Snyder, Nebr. Buls. 105, 117; Thalman, Nebr. Bul. 343; Baker, Nebr. Bul. 350; Brouse, Nebr. Bul. 357; Brenner, Fleming, and Smith, Nev. Rpt. 1948; Miller and Morrison, N.Y. (Cornell) Bul. 890; Langford, Douglas, Richard, and Buchanan, N.D. Bimo. Bul., 16, 1954, No. 6; Darlow, Campbell, Heller, and Briggs, Okla. Bul. 296; Darlow, Ross, and Stephens, Okla., Jour. Anim. Sci., 7, 1948, p. 536; Nelson, Darlow, and Campbell, Okla. Misc. Pub. MP-27; Potter and Withycombe, Ore. Bul. 182; McCone, S.D. Bul. 407; Hobbs and Moorman, Tenn. Farm and Home Sci., No. 1; Maynard and Hulme, Utah Bul. 250; Kincaid, Copenhaver, and McClaugherty, Va. Rpt. 1950–53; Hultz, Wyo. Bul. 134; Wyo. Rpts. 1928, 1929; West Va. Bul. 186; Sheets and Tuckwiller, U.S.D.A. Buls. 1042, 1431; Black, U.S.D.A. Cir. 408.
29. Willhite and Rouse, Colo. Farm and Home Res., 5, 1954, No. 1.
30. McCampbell and Aicher, Kan. Annual Cattlemen's Roundup, 1942.
31. McCampbell et al., Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1932; Brouse, Nebr. Bul. 357.
32. Duitsman and Kessler, Kan. Cir. 322.
33. Ga. Coastal Plain Bul. 44; Smith, Good, and Cox, Kan. Cir. 297; Smith et al., Kan. Cir. 308; Lantow, New Mex. Buls. 161, 185; Darlow, Ross, and Stephens, Okla., Jour. Anim. Sci., 7, 1948, p. 536; Nelson, Darlow, and Campbell, Okla. Misc. Pub. MP-27.
34. Grimes, Ala. Bul. 231; Grimes, Sewell, and Cottier, Ala. Cir. 71; Shealy, Fla. Rpts. 1929, 1930; McCampbell and Winchester, Kan. Cir. 92; McCampbell, Winchester, and Marston, Kan. Cir. 97; McCampbell et al., Kan., Fort Hays Branch Sta., Annual Cattlemen's Round-up, 1922, 1923, 1925, 1926, 1927, 1928, 1929, 1930, 1931, 1932, 1934; Smith, Cox, and Fansher, Kan. Cir. 297; Smith, Baker, Cox, and Holland, Kan. Cir. 322; Good, Ky. Bul. 297, Ky. Cir. 75; Waters, Mo. Bul. 75; Hedrick, Brady, and Dyer, Mo., Jour. Anim. Sci., 13, 1954, p. 969; Williams, Clark, and Patton, Mont. Bul. 407; Curtis, Farley, and Peden, N.C. Bul. 243 and U.S.D.A. Bul. 954; Darlow et al., Okla. Bul. 296; Nelson et al., Okla. Misc. Pubs. MP-22, 43; S.C. Rpt. 1923; Willson, Tenn. Bul. 125; Duncan et al., Tenn., Jour. Anim. Sci., 10, 1951, p. 1070; Hunt, Va. Bul. 215; Kincaid and Carter, Va. Rpt. 1947–49; Sheets and Tuckwiller, West Va. Bul. 186 and U.S.D.A. Bul. 870; Sheets, Livesay, Tuckwiller, and Semple, West Va. Bul. 191 and U.S.D.A. Bul. 1251; Wilson, Tuckwiller, and Sheets, West Va. Bul. 218; Livesay, West Va. Cir. 40; Hays, Wyo. Cir. 17; Sheets, U.S.D.A. Cir. 166; Black and Mathews, U.S.D.A. Tech. Buls. 192, 565; Black and Clark, U.S.D.A. Tech. Bul. 628.
35. Aicher, Kessler, and Weber, Kan. Cirs. 260, 271.
36. Albaugh and Strong, Cal. Cir. 433.
37. Chambers, Whatley, and Campbell, Okla. Misc. Pubs. MP-27, MP-34.
38. Pope et al., Okla. Misc. Pub. MP-43.
39. Bennett, Stoddart, and Harris, Utah Farm and Home Sci., 10, 1949, No. 2; Withycombe, Potter, and Edwards, Ore. Bul. 271.
40. McCampbell, Kan., Amer. Soc. Anim. Prod., Proc. 1920.
41. Guilbert and McDonald, Cal., Amer. Soc. Anim. Prod., Proc. 1933.
42. Guilbert and Gregory, Cal., Jour. Anim. Sci., 11, 1952, pp. 3–16.
43. Mumford, Ill. Bul. 83; Skinner and Cochel, Ind. Buls. 115, 129; Haney, Kan. Bul. 132; Smith, Nebr. Buls. 90, 93; Burtis, Okla. Rpts. 1900, 1901.
44. Klosterman, Kunkle, Bentley, and Burroughs, Ohio Res. Bul. 732.
45. Duitsman and Kessler, Kan. Cir. 322.
46. Stanley and Scott, Ariz., mimeo. rpt.; Hickman, Rinehart, and Johnson, Id. Bul. 209; Peters and Carnes, Minn. Bul. 200; Hackedorn, Sotola, and Bean, Wash. Bul. 186.
47. Good and Horlacher, Ky. Bul. 264.
48. Ariz. Rpt. 1922; Rusk, Ill., Breeder's Gaz., 61,

1912, p. 1041; Skinner, Cochel, and King, Ind. Buls. 136, 153, 163, 167; Evvard, Iowa, Breeder's Gaz., 61, 1912, p. 1040; Allison, Mo. Bul. 112; Thalman, Nebr. Bul. 347; Tomhave and Hickman, Penn. Bul. 133.

49. Pope, Humphrey, Heller, and Campbell, Okla. Misc. Pub. MP-31.
50. McCampbell, Kan., Amer. Soc. Anim. Prod., Proc. 1932; see also: Duncan, Tenn. Rpt. 1945.
51. Snapp and Knox, Ill. Bul. 328; Rusk and Snapp, Ill. Rpts. 1935, 1936, 1937; Skinner and King, Ind. Buls. 265, 281, 291; Scholl, McDonald, and Heady, Iowa Farm Sci., 6, 1951, No. 5; Smith, Good, Cox, and Mackintosh, Kan. Cirs. 273, 283; Smith, Cox, and Baker, Kan. Cir. 308; Ky. Rpts. 1934, 1935; Miss. Rpt. 66; Waters, Mo. Bul. 76; Weaver, Moffett, and Comfort, Mo. Bul. 387; Weaver and Dyer, Mo. Bul. 627; Baker, Nebr. Buls. 281, 307, 315; Nebr. Rpt. 1942; Miller and Morrison, N.Y. (Cornell) Bul. 890; Gerlaugh, Ohio Bimo. Buls. 138, 144; McCone, S.D. Rpt. 63; Tenn. Rpt. 64; Tex. Rpt. 1947–49; Wyo. Rpt. 1943; Black and Wilson, U.S.D.A. Tech. Bul. 889.
52. Bull, Snapp, and Rusk, Ill. Bul. 475; McCampbell, Mackintosh, et al., Kan. Rpts. 1926–28; 1928–30; 1930–32; 1932–34, and Amer. Soc. Anim. Prod., Proc. 1927; Pearson and Miller, N.Y., Jour. Anim. Sci., 9, 1950, pp. 13–19; Hunt, Kincaid, and Carter, Va. Bul. 458; Longwell, West Va. Bul. 274; Barbella, Tannor, Hankins, and Hunt, U.S.D.A. and West Va., Jour. Agr. Res., 64, 1942, pp. 517–521.
53. Grimes, Ala. Bul. 361; Kidder and Beardsley, Fla. Bul. 493; Browning et al., Iowa Rpt. 1948–49; McCampbell et al., Kan. Rpts. 1936, 1938; Bray, La. Bul. 296; Means, Miss. Bul. 329; Miller and Morrison, N.Y. (Cornell) Bul. 890; Ross et al., Okla. Misc. Pub. MP-11; Pope, Humphrey, Stephens, and Heller, Okla. Misc. Pub. MP-34; Duncan et al., Tenn. Rpts. 1945, 1947; Jones, Hall, Jones, and Black, Tex. Bul. 564; Jones, Jones, Hall, and Neal, Tex. Bul. 599; Hunt, Va. Rpts. 1918, 1927–31; Wash. Bul. 455; Ensminger, Law, Cunha, and Schwendiman, Wash. Bul. 483; Wilson and Livesay, West Va. Buls. 244, 254, 263; Black and Clark, U.S.D.A. Tech. Bul. 628; Black et al., U.S.D.A. Tech. Bul. 717; Savage and Heller, U.S.D.A. Tech. Bul. 943.
54. Jackson, Tenn. Rpt. 1947; Kincaid, Va. Rpt. 1950–53.
55. Kidder and Beardsley, Fla. Bul. 493; Smith and Cox, Kan. Cir. 297; Smith, Baker, Cox, and Holland, Kan. Cir. 308; Baker and Jackson, Nebr. Quarterly, 3, 1954, No. 2; Pope, Humphrey, Stephens, and Heller, Okla. Misc. Pub. MP-34.
56. Smith and Cox, Kan. Cir. 297; Tex. Bul. 724.
57. Mumford, Mo. Bul. 90; Trowbridge and Moffett, Mo., Amer. Soc. Anim. Prod., Proc. 1931; Gerlaugh, Ohio Bimo. Bul. 205; Darlow et al., Okla. Bul. 296; Ross et al., Okla. Misc. Pub. MP-11.
58. Ariz. Rpt. 1947; Kidder, Fla., Jour. Anim. Sci., 7, 1948, p. 537; Rusk et al., Ill. Cir. 586; Mott, Ind. Rpt. 1943; McCampbell, Winchester, and Marston, Kan. Cir. 97; Templeton, Miss. Bul. 268; Waters, Mo. Cir. 24; Shepperd, N.D. Bul. 217; Potter and Withycombe, Ore. Bul. 193; Ensminger et al., Wash. Bul. 444; Sarvis, U.S.D.A. Bul. 1301.
59. Garrigus, Ill., Amer. Soc. Anim. Prod., Proc. 1934.
60. Ky. Rpt. 1949.
61. Hentges, Cunha, and Killinger, Fla. Rpt. 1953; Johnson, Hickman, Rinehart, and Hodgson, Id. Bul. 270.
62. Skinner and Cochel, Ind. Bul. 142; Culbertson and Hammond, Iowa, mimeo. rpt.; Bohstedt, Ohio Bimo. Buls. 123, 129.
63. Garrigus, Ky. Cir. 494; Klosterman and Hamill, Ohio Farm and Home Res., No. 293; Pope, Acker, Humphrey, and Heller, Okla. Misc. Pub. MP-43; Tenn. Rpt. 1951.
64. Mitchell, Hamilton, Bull, and Olson, Ill. Rpts. 1931, 1932.
65. McCampbell and Winchester, Kan. Cirs. 86, 92.
66. Johnson, Rinehart, and Hickman, Id. Bul. 292; Ill. Rpt. 1938–47; Smith, Cox, and Baker, Kan. Cir. 308; Branaman and Harrison, Mich. Quar. Bul., 29, 1947, No. 4; Branaman and Harrison, Mich., Jour. Anim. Sci., 8, 1949, pp. 633–634; Deese, Patterson, and Lindley, Miss. Farm Res., 17, 1954, No. 5; Dyer and Guyer, Mo., Jour. Anim. Sci., 9, 1950, p. 674; Miller and Morrison, N.Y. (Cornell) Bul. 890; McCone, S.D. Bul. 407; Tenn. Rpts. 63, 64.
67. Miller and Morrison, N.Y. (Cornell) Bul. 890.
68. Weaver and Dyer, Mo. Bul. 627; Livesay, West Va. Bul. 296.
69. Good and Harris, Ky. Bul. 332.
70. Williams, Ariz. Rpt. 1920; Rusk and Snapp, Ill. Rpt. 1932; Trowbridge and Moffett, Mo. Bul. 300; Gramlich and Thalman, Nebr., mimeo. rpt.
71. Snapp, Beef Cattle, 4th Ed., 1952, pp. 572–574.
72. Snapp, Beef Cattle, 4th Ed., 1952, p. 574.
73. For detailed discussions of range beef cattle production in the West see: Sampson, Livestock Husbandry on Range and Pasture; Hultz, Range Beef Production; Stoddart and Smith, Range Management; Stanley, Ariz. Tech. Bul. 79; Hart and Guilbert, Cal. Bul. 458; Guilbert and Rochford, Cal. Cir. 115; Costello, Colo. Exten. Bul. 383A; Saunderson and Chittenden, Mont. Bul. 341; Gray and Baker, Mont. Bul. 495; Hedges, Nebr. Bul. 215; Brennen et al., Nev. Buls. 162, 165, 169; Walker and Lantow, New Mex. Bul. 159; Pingrey, New Mex. Bul. 336; Johnson, N.D. Bul. 347; Potter, Ore. Bul. 220; Johnson, S.D. Bul. 255; Stoddart, Utah Bul. 314; Vass and Pearson, Wyo. Bul. 197; Wilcox and Parr, U.S.D.A. Farmers' Bul. 1395; Wilson et al., U.S.D.A. Bul. 1454, U.S.D.A. Tech. Bul. 45.
74. Baker and Quesenberry, U.S.D.A., Jour. Anim. Sci., 3, 1944, pp. 78–87.
75. Sheets, Baker, Gibbons, Stine, and Wilcox, U.S.D.A. Yearbook, 1921; see also: Grimes, Ala. Rpt. 1937; Hopkins, Goodsell, and Buck, Iowa Res. Bul. 272; Merrick and Efferson, La. Bul. 353; Brown, Branaman, and Propp, Mich. Quar. Bul., 21, 1938, No. 1; Wright, Mich. Quar. Bul., 30, 1947, No. 2; Sallee, Pond, and Crickman, Minn. Tech. Bul. 138; Newell and Grissom, Miss. Exten. Bul. 118; Curtiss and Miller, N.Y. Sta., Farm Economics, No. 130, 1942; Carpenter, N.Y. Farm Economics, No. 191, 1953; Foster, Hostetler, and Case, N.C. Bul. 310; Tomhave and Severson, Penn. Buls. 138, 150; S.D. Bul. 382; Reuss, Peterson, and Buchanan, Wash. Bul. 432; Cotton, U.S.D.A. Bul. 615; Sheets and Tuckwiller, U.S.D.A. Bul. 1024; Black, U.S.D.A. Farmers' Bul. 1218.
76. Snapp, Beef Cattle, 4th Ed., 1952, pp. 561–562.
77. Black, U.S.D.A. Farmers' Bul. 1218.
78. Cotton, U.S.D.A Bul. 615.
79. Ill. Rpt. 1948; see also: VanArsdall and Cleaver, Ill. Cir. 714.

80. Duncan and Hazlewood, Tenn. Rpts. 1943, 1944, 1945; Bohstedt, Humphrey, and Roche, Wis. Bul. 420.
81. Evvard and Henness, Iowa, Amer. Soc. Anim. Prod., Proc. 1924.
82. Snapp, Beef Cattle, 4th Ed., 1952, p. 236.
83. Annual reports of Livestock Conservation, Inc.
84. Ward, U.S.D.A. Bul. 25; Pingrey, New Mex. Bul. 307; New Mex. Rpts. 62, 63, 64; Ore. Bul. 401; McCall and Hackedorn, Wash. Bul. 352.
85. Culbertson, Evvard, and Hammond, Iowa Bul. 271; Gramlich, Nebr. Bul. 229; Gramlich and Thalman, Nebr. Bul. 252; Bohstedt, Ohio Bimo. Bul. 93–94.
86. Niedermeier, Allen, Hanning, and Bray, Wis., Jour. Anim. Sci., 14, 1955, p. 1232; Niedermeier, Allen, and Bray, Wis., Jour. Dairy Sci., 38, 1955, p. 622.
87. Ragsdale, Mo. Bul. 490; Dowler, Ohio Bul. 495; Bechdel, Penn. Rpt. 1917; Bohstedt, Humphrey, and Roche, Wis. Bul. 420.
88. Dickey, Me. Farm. Res., 3, 1955, No. 1.
89. Swanson, Hinton, and Wylie, Tenn. Farm and Home Sci., No. 15.
90. Fountaine and Parrish, Kan. Rpt. 1948–50; Niedermeir, Allen, Hanning, and Bray, Wis., Jour. Anim. Sci., 14, 1955, p. 1232.
91. Hopper, Gardner, and Johnson, Ill., Jour. Dairy Sci., 37, 1954, pp. 431–435; Krauss, Monroe, and Hayden, Ohio Spec. Cir. 57.
92. Gardner, Nevens, Folkerts, and Johnson, Ill., Jour. Anim. Sci., 11, 1952, pp. 761–762.
93. Krauss and Monroe, Ohio Bimo. Bul. 241.

CHAPTER XXX

GENERAL PROBLEMS IN SHEEP PRODUCTION

I. Factors Affecting Sheep Husbandry

1260. Sheep production in the United States.—More than two-thirds the total number of sheep in this country are in the western states, where most of them are kept under range conditions in bands of from 1,000 to 3,000 head. Differing widely from this type of sheep production, sheep raising in the rest of the country is usually combined with other types of farming and commonly there are only 25 to 100 breeding ewes in each flock.

Usually, sheep raising is not the main source of income on farms where there are farm flocks, but because of its particular advantages, it is combined with other enterprises. Sheep do not need expensive buildings or equipment, the foundation animals are relatively cheap, and the flock can be increased rapidly. Sheep require but little labor during the busy summer, and the cares of lambing time can be over before spring work begins. The wool and the market lambs provide two sources of income each year, and returns come quickly, for lambs may be marketed 9 months after the ewes are bred. While excelled by pigs in economy of meat production, lambs require slightly less feed per pound of gain in weight than do fattening calves.

Sheep Keep Lanes and Fence Rows Clean

On many farms where most of the income is derived from other sources, a flock of sheep brings additional returns, since they consume much forage that would otherwise be wasted.

Sheep are especially adapted to grazing on rough and hilly land, and therefore farm flocks are most common where much of the land is unsuited for tillage. Sheep are without equals as weed destroyers, for they will eat nearly all of the common weeds, and they grind their

feed so finely that they destroy most weed seeds. A moderate-sized farm flock can often secure no small part of its feed by cleaning up the lanes, stubble fields, and fence rows. Although such waste should be fully utilized, one should not rely too largely on it. To secure good results from sheep, they must have sufficient feed at all times.

The effectiveness of sheep in cleaning out weeds is shown by the fact that some sugar cane growers in Louisiana use sheep to control Johnson grass in the cane fields.[1] Other farmers graze sheep in tung orchards to clean out weeds and brush. Not only is much labor thus saved, but also the sheep pay in wool and mutton for doing the work.

For success with sheep, it is even more essential than with other classes of stock that they be given careful attention, especially during the periods of breeding, lambing, and weaning. However, the principles of feeding and management are relatively simple. In some districts the dog nuisance is a serious obstacle in raising sheep, but fortunately several states have effective dog laws which protect the sheepman. Also, the flock may be safeguarded by means of fences, corrals, and trained dogs.

Usually, there should be at least 40 ewes in a farm flock, so as to reduce the expense per head for shelter, equipment, and labor, and the cost of keeping a good ram. Often the flock can advantageously be much larger than this, but if a farm is too heavily stocked with sheep, the troubles from stomach worms and other parasites are greatly increased. For this reason, but few farm flocks contain more than 200 ewes.

1261. Types of sheep.—The original fine-wool or Merino sheep were developed primarily for the production of wool and have bodies which, like those of dairy cows, are angular in form. At the other extreme are the mutton sheep, comprising the medium- and long-wooled breeds, which were developed primarily for the production of meat, with wool secondary. In shape of body these breeds resemble the beef breeds of cattle, being blocky and compact. The Rambouillets and the Delaine-Merinos were developed from the original Spanish Merinos to secure a fine-wool sheep that would furnish more mutton.

On the western ranges sheep carrying some mutton blood are desired, so that the lambs will yield good carcasses. However, unless the range ewes have considerable fine-wool blood, they will lose both their hardiness and their herding instinct and will scatter on the range, so that many will be lost or fall prey to wild animals. A system of cross breeding is therefore followed in range flocks, or such breeds as the Corriedale and the Columbia are used, which have been developed by crossing fine-wool and mutton breeds.

It is outside the field of this volume to discuss the characteristics or merits of the different breeds of sheep. Tests have been conducted at several experiment stations to compare various breeds or to determine the relative value of rams of different breeds for crossing on native or scrub ewes. These studies show that lambs of the fine-wool type are slower in maturing than lambs of the mutton breeds and therefore usually make smaller daily gains and require somewhat more feed for each pound of gain.

Among the mutton breeds, there may be quite as much difference in gaining capacity and economy of gain between various strains of one breed as there is between the different breeds. In deciding upon the breed to raise, one should therefore select the breed that seems best adapted to his own local conditions and to the requirements of his particular market.

1262. Building up the farm flock.—Often the most economical way for a farmer to establish a flock of sheep is to buy young, thrifty western range ewes of good conformation. These are commonly less infected with internal parasites than are native eastern ewes. By the continued use of good purebred rams of the same mutton breed, a flock of excellent mutton type and conformation may soon be built up that can scarcely be distin-

guished from purebreds. Even the lambs of the first cross will show pronounced improvement in mutton characteristics.

If native ewes are purchased locally to start the flock, it is important that they be vigorous, thrifty, free from disease, and of as uniform breeding as possible. In certain sections, native fine-wool ewes can be purchased more cheaply than ewes of mutton type. Provided they are thrifty, they make desirable foundation stock for building up a farm flock by the use of purebred mutton rams.

If one already has a flock of ewes, but they are of rather poor quality, he can make rapid improvement and thereby greatly increase the income from his sheep by using only a good purebred ram. For example, in North Carolina experiments half-blood ewes from purebred Hampshire or Shropshire rams and unimproved dams averaged 108 lbs. in weight, sheared 5.0 lbs. of wool per head, and produced lambs of good quality that averaged 73 lbs. in weight at 5 months of age.[2] Native ewes weighed only 70 lbs. and sheared only 3.1 lbs. of wool of shorter staple. Their lambs, sired by a scrub native ram, averaged only 51 lbs. at 5 months of age and yielded low-grade carcasses. Similar striking examples of the rapid improvement through the use of good purebred rams have been reported by the Kentucky, Mississippi, Nevada, Oklahoma, South Carolina and West Virginia Stations.[3]

1263. Lambs preferred to older sheep.—The tender, juicy, well-flavored meat from lambs is in far greater demand than mutton from older sheep. Hence, fat lambs sell for a much higher price per hundredweight than do older animals. Also, lambs make much cheaper gains than do older sheep. Thus, in a Kansas trial the feed cost of 100 lbs. gain was 56 per cent more for yearlings than for lambs, and in a Texas test 35 per cent greater.[4] For these reasons, practically all the lambs that are raised for meat are marketed before they are a year old.

Most stockmen who fatten western feeder sheep for the market prefer lambs. Though they cost more per hundredweight as feeders than do older animals, they sell for so much more when fat that there is usually a greater margin between cost and selling price per hundredweight, and hence a greater profit in fattening them. Some men make a practice of fattening old ewes, which can often be obtained at low prices. Such animals must be carefully selected and require expert care and good feed.[5] In the West they are often fed largely on beet pulp, as this is especially suited to those with "broken mouths," or poor and missing teeth.

II. Nutrient Requirements of Sheep

1264. Importance of plenty of good roughage for sheep.—For success with sheep, it is essential that they have an abundance of first class roughage. This means plenty of good pasture throughout the growing season and a liberal supply of good roughage in winter.

High-quality roughage is even more important for sheep than it is for dairy cattle or beef cattle. For example, it has been shown in the preceding chapter that if beef cows are in good condition in the fall, they generally have a satisfactory calf crop when wintered on straw as the only roughage, with supplements to furnish sufficient protein and minerals. However, Indiana experiments show that such a ration is very inadequate for pregnant ewes.[6]

In these experiments the results were decidedly unsatisfactory when ewes were wintered on oat straw, grain, salt, and a rather small amount of corn silage, even though soybean oil meal, ground limestone, and bone meal were added to furnish plenty of protein, calcium, and phosphorus. The lambs tended to be weak at birth and the ewes did not supply enough milk for good growth of their offspring. On the other hand, the results were excellent when high-quality alfalfa hay was fed.

These and later Indiana studies showed that the beneficial effects of the good legume hay were due in part to unknown vitamins or other factors, in addi-

tion to protein, calcium, and the common vitamins. The results were fair on corn silage as the only roughage, with a proper amount of protein supplement and a simple mineral mixture. However, alfalfa hay or dehydrated alfalfa meal contributed something additional to the well-being of the ewes and their lambs. Lambs from ewes receiving some alfalfa had a lower rate of mortality.

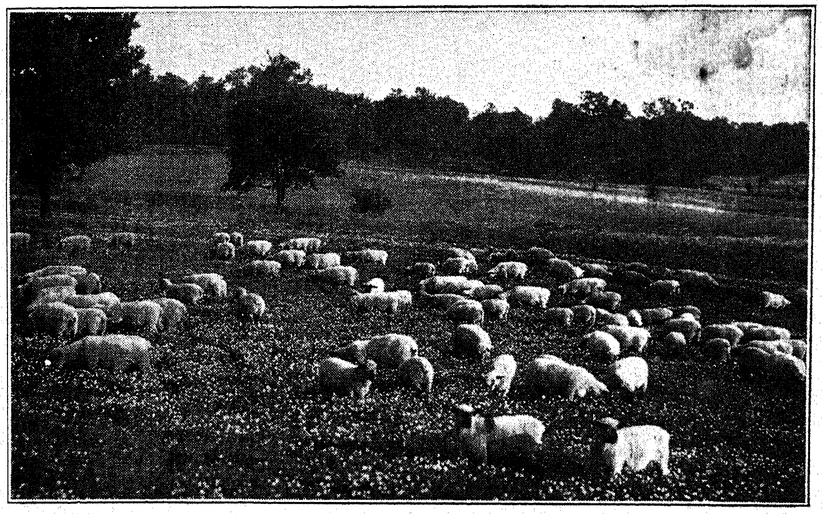
These and other experiments show that whenever possible, ewes should be supplied with plenty of well-cured legume hay in winter, or with good mixed hay that has a considerable proportion of legumes. Silage is also very satisfactory, especially as part of the roughage. (1307)

To be suitable for sheep feeding, grass hay must be cut early and be well cured. It has been shown previously that in Ohio experiments timothy hay cut in early bloom was satisfactory for pregnant ewes, when properly supplemented. (566) On the other hand, the results were very poor with late-cut timothy hay as the only roughage.

High-quality roughage, especially legume hay or silage, is also necessary for the best results in fattening lambs, as is emphasized in the following chapter. (1331)

1265. Nutrient requirements; feeding standards.—Detailed information concerning the amounts of nutrients required by various classes of sheep is given in the feeding standards presented in Appendix Table III. These state the amounts of dry matter, digestible protein, and total digestible nutrients to be fed per head daily. Net-energy recommendations are also given, so that rations can be computed on the net-energy basis, if desired. The standards also state the amounts of calcium, phosphorus, and carotene advised per head daily for the various classes of sheep.

These standards are based on studies by the author of the results of the experiments that have been conducted to find the nutrient requirements of sheep, especially the recent studies on the protein requirements of ewes and of fattening lambs, which are reviewed in the following articles. Full consideration has also been given to the report of a special committee of the National Research Council, entitled "Recommended Nutri-

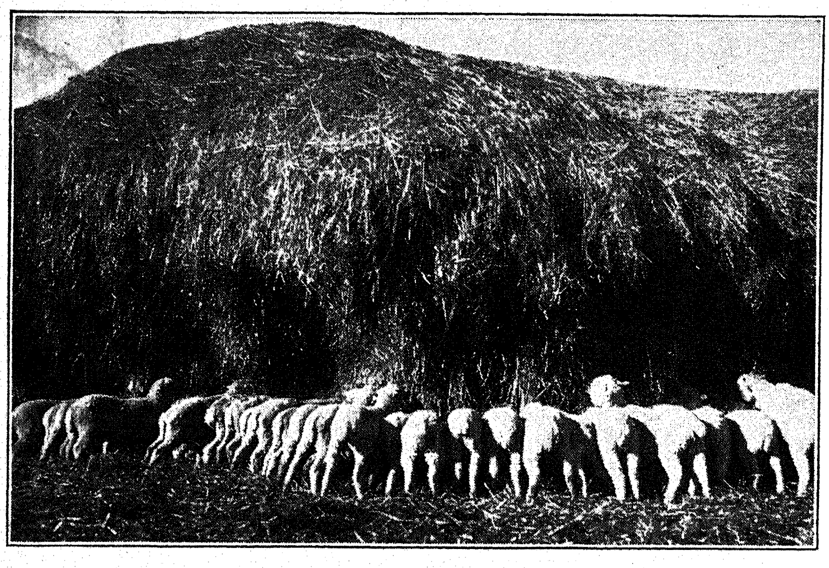


GOOD ROUGHAGE IS ESSENTIAL FOR SHEEP

For success with sheep, it is essential that they have plenty of first-class pasture throughout the growing season and a liberal supply of good roughage in winter.

ent Allowances for Sheep,"[7] and to the modifications of these allowances presented by Kammlade.[8]

To serve as guides in selecting well-balanced, efficient rations, several example rations are given in Appendix Table VII for breeding ewes and for fattening lambs. These example rations show the approximate amounts of various feeds needed per head daily for the different classes of sheep. They also show when protein supplements are needed to balance the ration, and the amount of supplement that should be supplied.



STRAW IS UNSATISFACTORY AS THE ONLY ROUGHAGE

Straw is a very poor feed for sheep. However, when hay is scarce, a limited amount of straw can be fed along with legume hay or legume hay and silage.

1266. Amounts of protein for ewes.—Since wool fibers are composed almost entirely of protein, sheep need a somewhat greater proportion of protein in their rations than would be required if they were not making this protein product. However, extensive recent studies at the North Dakota Station and the Lethbridge Station in Alberta, Canada, show that if mature ewes come off good summer pasture, they can be wintered satisfactorily up to lambing time on considerably less protein than was formerly thought necessary.[9] Other information on the subject is furnished by recent Montana, Oklahoma and South Dakota trials.[10]

During the last 4 to 6 weeks of pregnancy, ewes need more protein than previously, because the growth of the fetus is then most rapid. After lambing, considerably more protein is required, in order to secure the good milk flow necessary for rapid growth of the lambs.

The experiments have shown that mature ewes in good condition in the fall will generally produce thrifty lambs when they are wintered, up to 4 to 6 weeks before lambing, on a ration that has only 7 per cent protein supplying only 0.10 lb. digestible protein a day. During the last weeks of pregnancy, at least 10 to 11 per cent of protein is needed in the ration.

Though thrifty lambs have been produced on these very low levels of protein, the wool production of the ewes is reduced. Somewhat more liberal amounts of protein are therefore recommended in the revised feeding standards given in Appendix Table III. Ewes that

are still growing need more protein than those which are mature.

The low levels of protein mentioned are successful only when the ewes have a ration that provides ample energy and is complete otherwise, having roughage of satisfactory quality. Also, it is essential that the ewes be well fed after lambing, or they may not yield enough milk to raise their lambs, especially if they have twins. After lambing, the ration should have not less than 11 per cent total protein, and should furnish at least 0.25 lb. digestible protein per head daily.

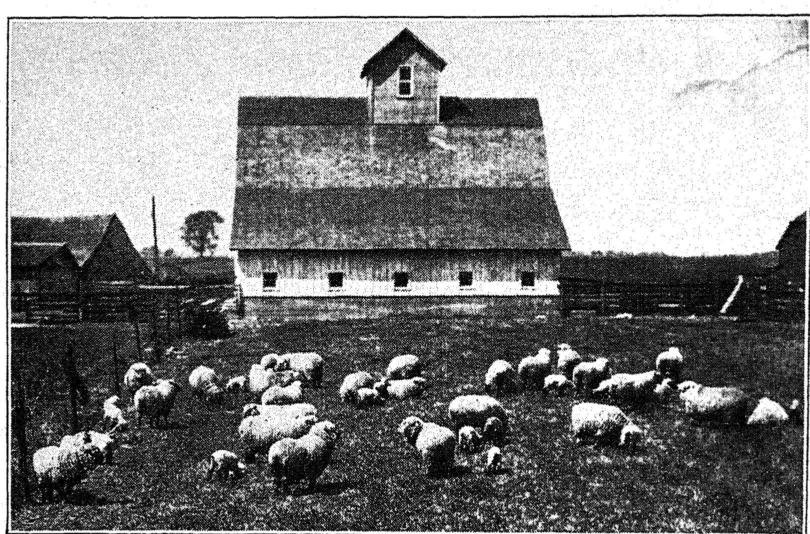
The disastrous effects of a ration too low in protein are shown by an Oklahoma trial.[11] When ewes were wintered on prairie hay alone or prairie hay plus starch to provide plenty of energy, 75 per cent or more of the lambs were dead at birth or died shortly afterwards. On the other hand, the results were satisfactory when a protein supplement was fed.

Rations for breeding ewes are discussed further in Chapter XXXI. (1306–1308)

1267. Amount of protein for fattening lambs.—The protein requirements of fattening lambs have been studied in a considerable number of experiments. Some of these experiments have been carried on to find whether or not it pays to add a protein supplement to various rations. In other trials the effect has been determined of adding various amounts of a protein supplement to typical rations for fattening lambs.

The most extensive of such experiments are those at the New York (Cornell) Station.[12] These New York studies have included both practical feeding experiments and also metabolism experiments in which the actual storage of protein in the body has been determined. In these experiments, lambs which usually weighed 50 lbs. or more at the start have been full-fed rations containing various percentages of protein until they were well fattened.

These experiments have shown that lambs of this age will make rapid gains and reach good finish on rations having about 10.3 per cent of total protein, on the air-dry basis. The nutritive ratios of such rations ranged between 1 : 7 and 1 : 8. Increasing the percentage of protein to 11.8 per cent produced slightly



EWES NURSING LAMBS NEED AMPLE PROTEIN

Ewes nursing lambs require a somewhat larger proportion of protein in their rations than do dairy cows.

more rapid gains, but the lambs were not so fat as those fed rations having 10 to 11 per cent protein.

Much lower amounts of digestible protein were advised by Mitchell for growing and fattening lambs.[13] However, in several of the New York experiments, lambs fed such low amounts of protein, in a ration otherwise adequate, have failed to make satisfactory gains.[14]

1268. Quality of protein.—It has been emphasized in Chapter V that at least when sheep are fed roughage of good quality, it is unnecessary to consider the *quality* or kind of protein supplied by ordinary feeds. (127) In New York metabolism experiments, growing lambs utilized the protein of corn gluten meal just as efficiently as the protein of soybean oil meal or dried skimmilk. This was true even when corn gluten meal furnished nearly all the protein in an experimental ration having very little natural roughage. For swine or poultry, the protein of corn gluten meal would have been decidedly inferior.

In practical feeding experiments with fattening lambs also conducted at the New York (Cornell) Station, corn gluten meal was about equal to soybean oil meal or linseed meal as the protein supplement to a ration of corn grain, corn silage, a very small amount of mixed hay, and ground limestone.[15] These results differ from similar New York experiments with fattening cattle, which have been discussed previously. (715) For fattening cattle, corn gluten meal was a decidedly less efficient supplement than linseed meal, soybean oil meal, or ground soybeans. This difference between the results with fattening lambs and with fattening cattle may be due to the fact that cattle full-fed on grain eat a much smaller proportion of roughage and a much larger proportion of grain than do fattening lambs.

It has been shown previously that for fattening cattle certain combinations of protein supplements are usually superior to such single supplements as cottonseed meal or corn gluten meal. (1167) However, in experiments with fattening lambs there has been little or no advantage in using such combinations of protein supplements as the following:[16] (1) Equal parts of linseed meal and cottonseed meal; (2) equal parts of gluten meal and either linseed meal or cottonseed meal; or (3) a triple combination of equal parts of the 3 supplements.

In a Colorado trial Purdue Supplement A, the use of which for beef cattle has been previously discussed, was not superior to soybean oil meal as the supplement to corn silage for fattening lambs.[17] (1178)

Although the quality of protein in protein supplements is not ordinarily important when sheep are fed good roughage, it may make a difference when the roughage is poor. Peas, which are low in methionine, the essential sulfur-containing amino acid, were not so good as linseed meal or alfalfa hay, fed as the supplement to poor grass hay for ewes in a Canadian trial.[18] In North Dakota studies with ewes the utilization of protein was improved when methionine was added to certain experimental rations in which peas supplied most of the protein.[19] It has been shown in Chapter XXII that, even with good roughage, raw beans are not satisfactory as the only protein supplement for fattening lambs. (844)

Wool is very rich in cystine, one of the two sulfur-containing amino acids, but there is apparently no lack of cystine in ordinary rations that are otherwise satisfactory for sheep.[20] If sheep are fed a ration unusually low in cystine, there may possibly be a benefit from using a protein supplement high in this amino acid or in methionine, the other sulfur-containing amino acid. Thus, in an Australian test with Merino sheep, whose wool production is high, blood meal (a feed rich in cystine) gave excellent results as a supplement to pasture grass that was exceedingly low in cystine.[21]

1269. Urea as a protein substitute.—The conditions necessary to enable ruminants to utilize urea as a substitute for part of the protein in the ration have been discussed in some detail in Chapter V. (129) For some unknown reason,

urea is generally a less satisfactory protein substitute for sheep than for dairy cows or for beef cattle.

A low-protein ration for sheep will be improved somewhat by the addition of urea. However, the results will generally be still better when the ration is balanced with one of the usual protein supplements.

Several metabolism experiments have proved that under proper conditions sheep can use urea as a partial substitute for protein.[22] But in most such studies urea has not equalled a protein supplement.

Sheep need more sulfur than do cattle, because of the richness of wool in cystine. Probably for this reason, if urea replaces a considerable part of the protein, the utilization may be improved by adding a sulfate, or even free sulfur, or else by adding methionine, the essential sulfur-containing amino acid. (**176**) However, even then the nitrogen in urea is apt to be less efficient than that in real protein.

Several experiments have been carried on to study the use of urea as a partial substitute for protein supplements in rations for fattening lambs.[23] When urea has replaced as much as one-half of the protein supplement commonly fed, the gains have been appreciably lower in most of the trials. Even when less urea has been used, there has been a tendency for the ration to be less satisfactory than with one of the ordinary protein supplements.

Urea has produced somewhat better results when used as a partial protein substitute for wintering breeding ewes.[24] However, in the majority of the experiments, the urea-containing rations have not been fully equal to rations balanced with such a protein supplement as soybean oil meal or cottonseed meal.

1270. Adding a protein supplement to legume hay and grain.—Many experiments have been conducted to find whether or not it pays to add a protein supplement to a ration of grain and legume hay for fattening lambs. These trials have shown that when lambs are fed a liberal amount of good legume hay with corn or other grain, there is usually enough protein to produce very satisfactory gains, without the addition of any protein supplement.

This is because full-fed fattening lambs continue to eat considerable hay, even during the latter part of the fattening period. The proportion of hay in the ration is thus considerably larger than in the case of fattening cattle full-fed on grain.

Adding a small amount of protein supplement (0.10 to 0.15 lb. per head daily) to such a ration as alfalfa hay and corn for fattening lambs will commonly make a slight increase in the rate of gain, unless the hay is of especially good quality and high protein content. However, the increase will not average more than 0.05 lb. per head daily. The supplement usually stimulates the appetite of the lambs slightly, so that they eat more total concentrates (grain plus supplement) than they would if fed only grain and hay.

This stimulating effect of the protein supplement may be due to some other factor than the additional protein the supplement supplies. This is indicated by the fact that a ration of corn grain and good alfalfa hay, both full-fed, will usually have fully 12 per cent protein. This is more protein than lambs seem to need for maximum gains. (**1267**)

Though the addition of a protein supplement to a ration of corn and good legume hay increases the rate of gain a trifle, nearly as much feed is required per 100 lbs. gain as on the unsupplemented ration. It is therefore doubtful if it will ordinarily pay to add a supplement to such a ration, if the hay is of good quality and an abundance is fed.

If one desires to secure maximum gains, so as to have the lambs ready for market as soon as possible, it may be advisable to feed a supplement. Otherwise, it is usually best to omit the supplement and to continue the lambs on feed the few days longer that will be needed to reach the desired finish. During the last few weeks of the fattening period, when lambs full-fed on corn tend to eat less hay than previously, there may be

more advantage in adding a small amount of supplement to the ration.

The effect of adding a supplement to a ration of corn and good alfalfa hay, both full-fed to fattening lambs, is shown by the results of 57 experiments in which either linseed meal or cottonseed meal has been added to this ration.[25] The average daily gain has been increased only 0.05 lb. by feeding the supplement. Not considering this slight difference in rate of gain, each 100 lbs. of protein supplement has saved an average of 94 lbs. corn and 88 lbs. hay in these many trials.

At the usual prices for the protein supplements in comparison with the prices of corn and hay, adding the supplement has increased the feed cost per 100 lbs. of gain in weight. Therefore, the addition of the supplement has generally not been profitable.

If barley, wheat, oats, or grain sorghum is fed with legume hay, the addition of a protein supplement does not cause even as much increase in rate of gain as adding a supplement to corn and legume hay.[26] This is because these grains generally are richer than corn in protein.

Red clover hay usually has somewhat less protein than does alfalfa hay. Nevertheless, adding a protein supplement to a ration of only shelled corn and good clover hay for fattening lambs increased the daily gain only 0.01 lb. in 9 trials and did not decrease the amount of feed required per 100 lbs. gain.[27]

1271. Adding a supplement when non-legume roughage is fed.—When fattening lambs are fed grain and only non-legume roughage, such as corn silage or grass hay, satisfactory gains cannot be secured unless enough protein supplement is fed to balance the ration. (698) When the roughage is mixed legume-and-grass hay or a combination of legume hay and corn or sorghum silage, a supplement is also usually needed, though a smaller amount is required.

If fattening lambs are given all the corn silage or sorghum silage they will eat and are also full-fed legume hay and grain, they will naturally eat somewhat less hay than when hay is the only roughage. Nevertheless, they will generally eat 0.75 to 1.00 lb. of hay per head daily, if it is of good quality. This will provide enough protein to make good gains, but it will usually pay to add about 0.15 lb. of a protein supplement to the ration. Such an addition will aid in keeping the lambs on feed, will increase the gains slightly, and will produce a better finish. Consequently, it will increase the selling price. When protein supplements are unusually high in price compared with grain, it may be most profitable to omit the supplement.

In 12 experiments with fattening lambs, the addition of 0.16 lb. per head daily of linseed meal or cottonseed meal to a ration of alfalfa hay, corn silage, and corn grain increased the daily gain 0.05 lb. on the average, raised the average selling price by 23 cents per hundredweight, and increased the average net return per lamb by 37 cents.[28] Not taking into consideration the more rapid gains or the increased selling price, each 100 lbs. of supplement saved 132 lbs. corn, plus 114 lbs. hay and 100 lbs. silage. Similar results have been secured in trials where a supplement has been added to a ration of corn, clover hay, and corn silage,[29] or to a ration of other grains fed with silage and legume hay.[30]

Whether or not it will pay to add a protein supplement to a ration of alfalfa hay, wet or dried beet pulp, and grain, will depend primarily on the amount of hay the lambs eat and on its quality.[31]

1272. Total digestible nutrients; net energy.—The amounts of total digestible nutrients and of net energy advised per head daily for ewes and for fattening lambs are stated in Appendix Table III. An abundance of good roughage alone will usually supply sufficient total digestible nutrients or net energy for breeding ewes in winter up to about a month or six weeks before lambing. A small amount of grain or other concentrates should then be fed, on account of the rapid growth of the unborn lambs at that time. Another reason why concentrates are then needed is that the capacity of the ewe to consume rough-

age is considerably reduced, because of the space in the abdomen that is occupied by the lamb or lambs and the fetal membranes.

It is emphasized in the next chapter that if ewes are severely underfed before lambing they frequently have weak lambs, and are unable to raise them because of a poor flow of milk. (**1305**) Underfed ewes are also more apt to have pregnancy disease. (**1314**)

Ewes that are suckling lambs need a liberal supply of total digestible nutrients. Therefore, ewes lambing before they go to pasture need a sufficient amount of concentrates, in addition to good roughage, to keep up a good milk yield. If they are on suitable pasture, they need be fed no concentrates.

In order to fatten lambs rapidly, so that they will reach the desired degree of fatness before they become too large, they must receive a liberal amount of grain or other concentrates, in addition to plenty of good roughage. (**1331**) However, restricting the roughage and feeding an undue amount of grain will lead to less efficient use of feed and greatly increase the danger of overeating disease. (**1333**)

1273. Addition of fat to rations.—When the price of low-grade animal fat is low, compared with an equal amount of energy in grain, it may be economical to add a small percentage of such fat to rations. (**914**)

In a Texas trial the addition of 5 per cent of tallow or grease to a mixed ration increased the gain slightly and reduced the feed cost per 100 lbs. gain, with the fat costing 1.8 times as much per pound as sorghum grain.[32] Adding 10 per cent or more of the fat to the ration decreased the gains.

In a New York trial, adding 6 per cent of yellow grease or tallow did not appreciably increase the rate of gain, and it slightly reduced the selling price of the lambs.[33] With the fat costing 2.4 times as much per pound as shelled corn, the return per lamb above feed cost was higher without the added fat.

Replacing part of the corn in a typical lamb fattening ration with 4 per cent of animal fat did not affect the digestibility of the ration in an Iowa trial.[34] A greater percentage decreased the digestibility. Hydrogenated animal fat, which had a very high melting point, was utilized less completely than was tallow or corn oil.

1274. Mineral requirements.—Except in the areas where there is a deficiency of one or more of the trace minerals, the only minerals that need consideration in feeding sheep under usual conditions are salt, calcium, and phosphorus. Calcium, phosphorus, and trace minerals are discussed in the articles which follow.

In districts where there is trouble from goiter in new-born lambs, the ewes should receive iodized salt during at least the latter half of pregnancy. (**170**) It is doubtful whether there is any benefit from using iodized salt in place of ordinary salt for fattening lambs, except possibly in areas where there is a decided deficiency of iodine. (**171**) Adding too much iodine to a ration may produce serious injury.[35]

There is no need to add complex mineral supplements to the usual rations of sheep.[36] (**187**)

1275. Salt.—Sheep show a special fondness for salt and consume considerably more salt per 100 lbs. live weight than do cattle. Under any ordinary conditions, they should be furnished salt regularly. When sheep are accustomed to salt, it is the best plan to let them have access to it in suitable boxes or other containers, so they can take what they wish. Ewes will usually eat one-fourth to one-half ounce of salt a day, and fattening lambs one-fifth to one-fourth of an ounce.[37]

In Iowa trials better results were secured from ewes fed one-fourth to one-half ounce of salt per head daily or allowed free access to salt, than when larger amounts were mixed with the feed or when no salt was supplied.[38]

Fattening lambs that were supplied with salt gained an average of 0.04 lb. more per head daily in 3 Kansas trials, than did others having no salt.[39] The

feed cost per 100 lbs. gain was considerably less with salt than without it.

Feeder lambs shipped from the western range have usually had no salt when in transit. Therefore, in starting them on feed they should gradually be accustomed to salt.

On the western ranges allowances of salt equivalent to one-fourth to one-half ounce per ewe daily (not counting the lambs) are considered reasonable.[40] Often the sheep are salted at intervals of 3 to 7 days, instead of daily. In the alkali districts, sometimes range sheep are not salted, but merely allowed to eat alkali. This is safe, if the alkali contains 85 per cent salt.[41]

1276. Self-feeding a mixture of protein supplement and salt.—Information has been given in previous chapters about self-feeding a mixture of protein supplement and salt to range livestock, instead of feeding the protein supplement daily. (**142, 1170**) This labor-saving method is used not only for beef cattle, but also for sheep. The precautions necessary in self-feeding such a mixture have been stated previously.

In California studies a mixture of 25 per cent salt and 75 per cent of protein supplement was successfully used for pregnant and lactating range ewes.[42] The high salt consumption had no injurious effects.

1277. Calcium and phosphorus.—Whether or not there will be any advantage in adding a calcium or a phosphorus supplement to rations for breeding sheep or growing and fattening lambs will depend entirely on the amounts of these minerals supplied by the feeds they receive. Whenever there is apt to be a deficiency of either of these mineral nutrients, a suitable mineral supplement should be provided, as advised in Chapter VI. (**149–150, 186**) The feeding standards in Appendix Table III state the amounts of calcium and phosphorus advised per head daily for various classes of sheep.

1278. Calcium.—When at least one-third of the roughage (on the dry basis) for sheep and lambs is legume hay or other legume forage, there will be abundant calcium. Experiments with breeding ewes[43] and with fattening lambs[44] have shown that under such conditions there is no benefit from adding ground limestone or some other calcium supplement to the ration.

There is generally no lack of calcium when sheep are on good pasture. However, if the soil is unusually low in the mineral, it is wise to provide a mineral mixture supplying calcium. Wyoming studies indicate that the occurrence of "broken mouths" in ewes on the Red Desert ranges of that state is due, at least in part, to a lack of calcium.[45]

When no legume hay or other legume forage is fed to sheep, there may be a decided lack of calcium in winter rations, especially where the forage is grown on soil very low in calcium. Calcium should then be supplied by adding 0.25 to 0.40 ounce per head daily of ground limestone or other calcium supplement to the ration, or else by letting the sheep have access to a suitable mineral mixture.

Experiments at the Kansas, Nebraska, and Texas Stations show that a lack of calcium is one cause of the poor results often secured when lambs are fattened on rations without legume forage.[46] Lambs fed sorghum silage or fodder as the only roughage, with corn or sorghum grain and cottonseed meal, made decidedly slower and more expensive gains than others that had alfalfa hay for roughage. However, when 0.25 to 0.40 ounce per head daily of ground limestone or pulverized oyster shell was added, much better results were secured. The results were similar in Minnesota and Ohio trials, in which prairie hay or timothy hay was the only roughage for fattening lambs.[47]

Likewise, in Ohio trials satisfactory results were secured with breeding ewes fed only timothy hay and corn silage for roughage, if the hay was cut in early bloom and if 0.8 ounce of ground limestone per head daily and a sufficient amount of protein supplement were added to the ration. (**566**)

In certain other trials there has been

an advantage from adding a calcium supplement to a ration containing no legume hay, while in others no advantage has resulted.[48] This difference in results is probably due to the fact that non-legume roughage varies widely in amount of calcium, depending on the calcium content of the soil.

If non-legume roughage is grown on soil fairly well supplied with calcium, it will take relatively little legume hay to provide enough additional calcium for fattening lambs. For example, in Indiana trials there was no benefit from adding a calcium supplement when fattening lambs were fed corn silage, corn grain, and cottonseed meal, with a full feed of good clover hay only every fifth day.[49]

As has been pointed out in the case of beef cattle, adding a calcium supplement to a ration that is marginal in phosphorus content may be definitely injurious.[50] (**1171**)

1279. Phosphorus.—Extensive experiments have been conducted by the Idaho Station to determine the phosphorus requirements of ewes [51] and of fattening lambs.[52] These investigations show that a phosphorus content of only 0.16 to 0.19 per cent in the entire ration (air-dry basis) is adequate for ewes during pregnancy. When they are suckling their lambs, their rations should have 0.23 per cent phosphorus.

The Idaho studies and also Oklahoma experiments show that for fattening or growing lambs, about 2 grams of phosphorus daily per 100 lbs. liveweight is sufficient.[53] Such rations will have approximately 0.17 per cent phosphorus on the air-dry basis.

When low-phosphorus rations were fed to pregnant ewes, abortion or weak lambs resulted. Phosphorus-deficient rations for fattening lambs resulted in low gains, poor utilization of feed, and depraved appetite.

There will commonly be no lack of phosphorus for ewes or fattening lambs when they are fed grain and plenty of good hay or other roughage, unless the forage is grown on land very deficient in phosphorus.[54] This is because the grains usually have 0.27 per cent or more of phosphorus and good hay generally has at least 0.19 per cent. Corn silage, reduced to the air-dry basis, has even more phosphorus, but the content in sorghum silage seems to be somewhat lower. When ewes are wintered on only good hay or hay and silage until a few weeks before lambing, they will usually have enough phosphorus, unless the forage is unusually low in phosphorus.

When sheep are wintered chiefly on mature, weathered range forage, as in many districts of the West, there may be a decided deficiency of phosphorus.[55] Also, there may be a serious lack of phosphorus when feeds that are particularly low in phosphorus form a considerable part of the ration for ewes or fattening lambs. Such feeds are beet pulp and beet molasses.

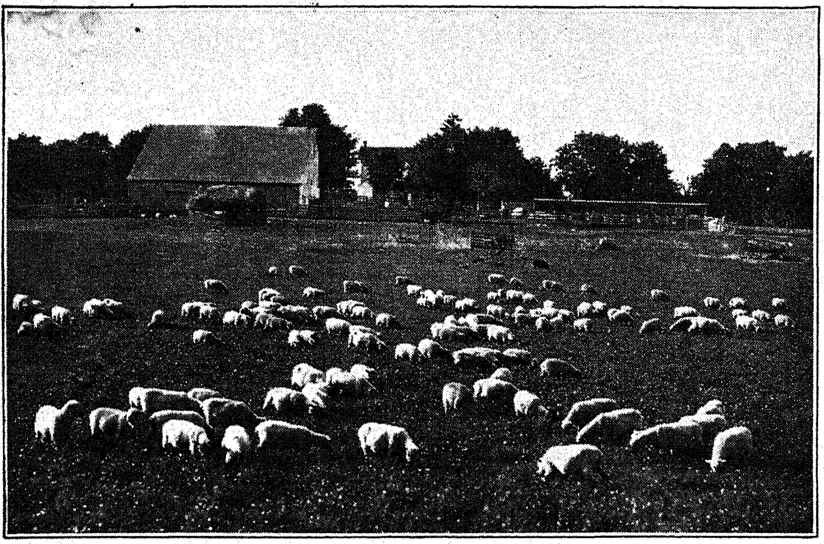
Whenever there is apt to be a lack of phosphorus, a low-fluorine phosphorus supplement should be supplied, as recommended in Chapter VI. (**158, 169**) Sheep on pasture seem to be less apt to show a lack of phosphorus than do cattle on the same pasture. This may be because sheep have a very selective habit of grazing.

When there is already an ample supply of calcium and phosphorus in the ration, forcing sheep to consume a calcium or phosphorus supplement may even be detrimental. For example, in the case of breeding ewes, too liberal a supply of these minerals may even perhaps cause more cases of difficult lambing, because of an increase in the size of the skeleton of the lambs.

1280. Trace minerals.—In an area where there is a deficiency of a trace mineral, it is essential that the lack be corrected, as has been emphasized in Chapter V. (**173, 175**) In other areas there is no advantage in using trace-mineralized salt instead of ordinary salt, or in supplying a mineral mixture that furnishes cobalt, copper, or iron.[56]

The striking benefits produced by a cobalt supplement in deficient areas are well shown by Wisconsin studies.[57] In certain sections of northern Wisconsin sheepmen were having disastrous results

in their flocks. For example, in one flock of 1,300 ewes and lambs, all but 200 died during the year. When a mineral mixture containing cobalt was supplied the sheep in these flocks, the troubles were entirely prevented. Later studies showed that when a mineral mixture containing both cobalt and bone meal was supplied for sheep on pasture, they were protected to some degree from injury from stomach worms. New York experiments have also shown the disastrous results from feeding lambs a cobalt-deficient ration.[58]



ABUNDANT SUPPLY OF VITAMINS ON GOOD PASTURE

Sheep on such pasture have an abundant supply of vitamins. Legume or mixed legume-and-grass pasture is also rich in protein and calcium.

Although the area around Cornell University, New York, is not decidedly deficient in cobalt, the content is apparently marginal. In 3 experiments fattening lambs gained appreciably more when cobalt was added to the ration, unless at least 0.1 lb. linseed meal was fed per head daily. This amount of linseed meal evidently furnished sufficient cobalt, as it is higher in the mineral than most other feeds.[59]

1281. Vitamin requirements—If sheep have plenty of good roughage, including pasture during the growing season, all of their vitamin needs are usually met. Pasture that is at all suitable for sheep is high in vitamin A value (carotene content). In the fall, sheep that have been on good pasture during summer will consequently have a considerable store of vitamin A in their bodies. (**192**) If ewes or lambs are then fed hay of reasonably good quality or other satisfactory roughage, they will have plenty of vitamin A.

It has been emphasized previously in this chapter that it is always advisable to provide pregnant ewes with high-quality roughage in winter. (**1264**) Experiments have shown, however, that if ewes have been on first-rate pasture during the growing season, they may produce normal lambs when fed roughage low in carotene during most of the winter.[60] It is not safe to continue such a ration too long, for the ewes may become depleted in vitamin A. They will then suffer from the deficiency, and the lambs may be born so weak that they soon die, or the milk of the ewes may have so little vitamin A that the lambs are seriously affected.

Under any usual conditions in the United States there is apparently no need of feeding a vitamin D supplement to sheep.[61] The fact that they are generally outdoors and exposed to sunlight much of the time, even in winter, protects them against any deficiency of vitamin D. Also, field-cured hay or fodder supplies the vitamin. However, as stated in Chapter VII, rickets sometimes occurs in New Zealand in lambs on pasture, for some unknown reason.[62] (201) This can be prevented by a vitamin D supplement.

The B-complex vitamins are synthesized through the bacterial action that normally occurs in the rumen of sheep. Thrifty sheep that are digesting their feed properly therefore have no lack of these vitamins.[63] If sheep are very debilitated because of infection with internal parasites, the administration of yeast, before they are treated to remove the parasites, may be beneficial in order to restore their appetite and build them up. (957)

In a Wisconsin experiment there was no advantage in adding a vitamin B_{12} supplement to the ration of ewes nursing lambs, or to the creep feed given the lambs.[64]

It has been found in experiments where new-born lambs were fed synthetic milk, lacking B-complex vitamins, that they need a supply in their food, before the rumen is developed.[65] Fortunately, ample amounts are provided by their mothers' milk.

The ordinary rations fed sheep supply ample vitamin E for successful reproduction. (223) It is shown in the next chapter, however, that the stiff-lamb disease can be prevented by feeding vitamin E supplements. (1315)

It has been mentioned previously in this chapter that the poor results produced by feeding chiefly low-grade roughage, such as straw, to pregnant ewes, may be due in part to the lack of unknown vitamins which are supplied by high-quality roughage. (1263)

1282. Water.—Plenty of fresh water should always be furnished sheep, under all ordinary circumstances. Ewes on dry feed in winter may drink as much as 1 gallon per head daily before lambing and 1.5 gallons or more when nursing lambs. Lambs that are being fattened on dry feed will drink 1.2 to 2 quarts or more of water a day.[66]

When sheep are fed succulent feeds, such as silage or roots, they drink correspondingly less water. In districts with very heavy dews, sheep on pasture may get along without other water, and likewise when they are fed large quantities of roots in winter. More water is needed in warm weather than when it is cooler, and fattening lambs drink more as their grain allowance increases.

Because of the danger of infection with internal parasites, drinking from stagnant pools must be avoided. It is not necessary to warm water for sheep in winter. In some regions sheep even have to eat snow during much of the winter for their water supply, and apparently are not injured.

1283. Antibiotic feed supplements.—The results of the experiments conducted to determine the effects of adding either aureomycin or terramycin to fattening lamb rations have varied.[67, 68] (966) A more favorable response has usually been secured under commercial feedlot conditions than with carefully controlled experimental conditions because of the difference in disease levels present. When needed an antibiotic feed supplement should be fed at a level of 10 milligrams per pound of total ration. Carcass quality is not affected by such an addition.

Under some conditions, the addition of antibiotics to the ration has resulted in some reduction of enterotoxemia or "overeating disease," although recent New Mexico results show no benefit.[69]

If an antibiotic produces a response in a given situation, the cost of the addition should be balanced against such factors as reduction in disease, increased gain, and improved feed efficiency, to determine its net effect.

Some experiments have been conducted to determine the effects on suckling lambs of adding an antibiotic supplement to the creep feed, or of implanting an antibiotic pellet in the head,

under the skin.[70] Here again, the results have differed decidedly. There have been no benefits in as many trials as there have been increases in rate of gain.

1284. Arsonic supplements; surfactants; tranquilizers.—Little information is yet available concerning the effect of arsonic supplements on lambs. In Illinois experiments with 3 different types of arsonic compounds, none proved consistently beneficial with either a typical lamb fattening ration or with a diet using wheat straw as roughage.[71] If such compounds are added to the feed care should be taken not to include toxic levels, especially if water consumption is limited.

In South Dakota trials the addition of a surfactant to a ration for fattening lambs did not increase the rate of gain.[72]

A new "chemobiotic" (tetra alkylammonium stearate or dynafac) has given variable results. Recent work reported by Washington showed no effect on weight gains, market grade, or price of commercial lambs receiving 1 gram per head daily of this compound in the feed. On the other hand, work by a commercial laboratory showed improved feed efficiency and increased daily gain compared with other lambs receiving antibiotics in the feed.

Lambs fed tranquilizers (reserpine or hydroxyzine) have shown inconsistent results. Purdue work showed no effect on daily gain or feed efficiency, while certain commercial work and Iowa experiments demonstrated a distinct response on both gain and feed efficiency. Since lambs vary greatly in their response to diets due to their origin, breeding, and environment, more research needs to be conducted on this subject before valid recommendations can be made.

1285. Hormones for lambs.—The effects of implanting pellets containing stilbestrol or other hormones under the skin in the heads of lambs have been studied in several recent experiments. The implantation of stilbestrol pellets has generally increased the rate of gain of fattening lambs and lowered the amounts of feed required per 100 lbs. gain.[73]

However, the quality of the carcasses has been lowered appreciably in most of the trials. Even more important, implanting stilbestrol has sometimes had very injurious effects on the lambs. It has caused prolapse of the uterus in ewe lambs, and in wethers has produced prolapse of the rectum and blockage of the urinary tract, resulting in "water belly." Some large lamb feeders have had severe death losses of fattening lambs, apparently caused by implanting stilbestrol pellets.

In addition, the stilbestrol may produce earlier closure of the break joint in lambs, so that the carcasses are classed as yearling, instead of lamb. This reduces the price appreciably.

More limited data are available concerning the effects of implanting pellets containing other hormones. A commercial product is being made that has a combination of two natural sex hormones —progesterone and estradiol. Favorable results were secured with such pellets in a Michigan trial and a Minnesota trial, but in a Virginia test 5 out of 8 lambs implanted with such pellets died from prolapse.[74] In another experiment the carcasses from the implanted lambs graded lower.[75]

Several experiments have been conducted to evaluate stilbestrol supplementation of fattening lamb rations, in a manner similar to fattening cattle. (1183) Adding 2 mgs. of stilbestrol per head daily in the feed of fattening lambs increased gains, and did not lower carcass quality or produce side effects in Iowa trials.[76] Increased levels of stilbestrol lowered the carcass quality.

On the other hand, in a Kansas trial even 2 milligrams of stilbestrol per head daily affected the quality of the carcasses.[77] In Minnesota experiments adding stilbestrol to the ration increased the gain in some cases, but not in others.[78] The results with fattening lambs thus apparently differ from those secured with fattening cattle and this compound is not widely used at present.

In a Tennessee experiment the addition of stilbestrol to the ration of lambs had no effect on digestibility, but it did increase the retention of protein, calcium, and phosphorus.[79]

III. Miscellaneous Problems in Sheep Husbandry

1286. Grinding or crushing grain.—There is no benefit from grinding or crushing most kinds of grain for sheep, except for old sheep with poor teeth, for young lambs up to 5 to 8 weeks of age, or perhaps when fattening lambs are being self-fed such a mixture as grain and chopped hay. It is wise to grind such hard seeds as hull-less barley or millet, and also screenings containing a considerable proportion of small weed seeds.

Also, recent Texas experiments with fattening lambs show that grinding appreciably increases the value of the grain of combine-type sorghums, which have smaller and harder seeds than other grain sorghums.[80]

If grain is processed for sheep, it should be ground coarsely or crushed, instead of being ground to a fine meal, for this is less palatable to them. Similarly, pea-size linseed cake or cottonseed cake is somewhat preferable to linseed meal or cottonseed meal for sheep feeding.

1287. Chopping or grinding hay, fodder, or stover.—Many experiments have been conducted to find whether or not it pays to chop or grind hay for sheep.[81] These tests have shown that when hay of good quality is fed in suitable racks or bunks and only as much is fed as will be cleaned up reasonably well, extra expense for chopping the hay is generally not warranted. There is still less reason for grinding hay, since sheep are apt to prefer long hay to that which is ground. If hay is stored in chopped form when it is put into the barn, it should not be chopped so fine that it is dusty. (407)

If the hay is rather stemmy and of poor quality, the sheep can be forced to eat more of the stems by chopping it. However, if one has plenty of hay, it is doubtful whether chopping is desirable even then. A better plan may be to feed an abundance of the hay, so the sheep can pick it over and eat only the more palatable and nutritious part. The refused part can be used for bedding or be fed to cattle being roughed through the winter or to idle horses.

When self-feeders are used for feeding grain to fattening lambs, often a mixture of cut or ground hay and ground grain is self-fed, instead of grain and hay separately, in order to lessen digestive disorders and reduce the death losses. (1335) Also, if one wishes to crowd hand-fed lambs on all the grain they will eat, digestive trouble may be lessened by mixing chopped hay with the grain.[82] A mixture of chopped hay and grain is sometimes fed in starting fattening lambs on feed.

If fattening lambs are fed hay (even good alfalfa hay) with great liberality, as is a common practice in the western states, there may be an appreciable saving through chopping or grinding it. In western experiments chopping alfalfa hay, not too fine, has increased its value 18 to 19 per cent,[83] and grinding the hay has made twice as large an increase in value.[84] In these western trials as much as 16 to 28 per cent of the long hay was not eaten by the lambs. When hay of good quality is fed in racks that prevent wastage, the saving through chopping or grinding will not average as much as in these trials. If hay is ground for sheep, it should not be ground too fine, for such a product is very dusty.

Whether it will pay to chop or shred dry corn fodder or stover or sorghum forage for sheep will depend on the proportion they would waste if the roughage were fed uncut, and also on the cost of such preparation. In a Texas test chopping sorghum hay for fattening lambs slightly increased the gains and saved one-third the hay, while in Colorado and Oklahoma trials it did not pay to chop sorghum hay or fodder or Sudan hay for lambs.[85]

1288. Pelleting feed.—Several experiments have been conducted recently to determine the effects of pelleting the entire ration for fattening lambs, or of pelleting only ground hay or else the concentrates.[86] In most of the trials in which the entire ration has been pelleted the gains and feed efficiency have been increased by pelleting, especially when

pellets containing the proper proportion of concentrates and hay have been self fed. However, often the cost of grinding and pelleting the grain and hay has been so high that the feed cost per 100 lbs. gain and the net return have been decidedly lower. In some of the trials the cost of such preparation has been $12 to $15 per ton.

There seems to be more advantage in pelleting the entire ration when the roughage is of rather poor quality, than when good roughage is fed.

In New Mexico trials with fattening lambs and yearlings, the gains were more rapid on pellets made from a mixture of ground sorghum grain, molasses, and ground stemmy alfalfa hay than when good long hay and whole sorghum grain were fed.[87] However, the cost of processing the pelleted ration was as high as $13.86 per ton.

If fattening lambs are fattened on pellets containing a mixture of concentrates and ground hay, it is wise to supply a little good long hay. Otherwise, they may show a great desire for such roughage, and manifest this by gnawing on feed racks and bunks.

Grinding the grain and pelleting the concentrate mixture alone for fattening lambs has not usually been profitable,[88] or grinding and pelleting the hay.[89]

1289. Shelter.—Sheep are so well protected from cold by their fleeces that they do not need warm shelter. Even in the northern states, one thickness of matched boards will make a barn or shed sufficiently warm, except for winter lambs. In the drier sections of the West, often no winter shelter is provided other than a windbreak to protect the sheep from cold winds and driving storms. If they are kept dry, sheep will stand a great degree of cold with no harm. On the other hand, too-warm quarters are injurious, for sheep sweat badly in winter when kept in a warm barn, and they are then apt to catch cold.

Ample ventilation is of great importance, but drafts should be avoided. With sheep it is more important than with other livestock that they be kept dry. Sufficient light, good drainage, and conveniences for feeding are other essentials of a good sheep barn. The doorways should be wide, to avoid injury when many animals attempt to rush through at once, in true sheep fashion.

In late spring and early summer the flock should be sheltered from cold rains, if possible, for the exposure may be dangerous, especially to young lambs. Even in the South, sheep should be protected from winter rains.

In summer, if there is no natural shade in the pastures, a movable shelter should be provided for shade, or the flock should have access to a darkened but well-ventilated shed. A fringed curtain of cloth or sacking through which the sheep may pass, will help to keep out flies.

Fattening lambs or sheep have an excess of heat on account of their liberal rations and therefore need less shelter than do breeding ewes. A well-bedded shed, opening to the south into a well-drained yard, is ideal for winter shelter, except perhaps in the extreme northern states. In 5 Indiana tests lambs thus sheltered made as rapid and as cheap gains and returned more profit than others housed in a well-ventilated barn.[90] In 3 trials at the Wisconsin Station, where the winters are colder, lambs housed in a well-ventilated barn and turned out daily for exercise gained a trifle more rapidly than did others housed in an open shed, partly boarded up for additional protection.[91] The average cost of feed was only 4.6 per cent higher for the lambs in the shed.

In the plains states and westward, no shelter is usually furnished for fattening lambs, except perhaps a windbreak. Any slight saving in feed through providing sheds is not sufficient to justify the expense.

In Nebraska and Idaho tests, providing an open shelter did not increase the gains or decrease the feed required per 100 lbs. gain.[92] In 3 trials in eastern Oregon, lambs having access to an open shed made slightly larger gains than others fed in a yard with no shelter, and required 3 per cent less feed for 100 lbs. gain.[93]

Where there is considerable rainfall or snowfall in winter, a shed may make more saving in feed. For example, in a Missouri trial yearling wethers fed in a yard without shelter required 19 per cent more feed than others which had access to a barn.[94]

1290. Exercise.—Sufficient exercise is essential for breeding ewes in winter, to insure strong, healthy lambs. The ewes should have access to a dry, sunny yard, well protected from wind and storm. To induce them to exercise on all fair days, roughage may be scattered in small bunches over a nearby field. If the snow is deep, paths should be broken out with a snow plow. On stormy days the sheep should remain indoors, for wet fleeces dry slowly in winter, and ewes that are close to lambing are better off without undue exercise.

For fattening lambs or sheep, it is preferable to limit the exercise, because too much exercise may reduce the gains. In 3 New York trials lambs confined to a roomy pen in a well-ventilated barn gained a trifle more than others allowed to run out during the daytime in a small yard.[95] The feed cost per 100 lbs. gain was 4 per cent less for the confined lambs.

1291. Feed troughs and racks.—Grain and roughage should be fed separately to sheep, except when a mixture of grain and chopped or ground hay is used for fattening lambs. Grain troughs should have a wide, flat bottom, to make the sheep eat the grain slowly. Hay racks should be so built that chaff and seeds will not fall upon the necks of the sheep and injure the quality of the wool. Combination grain-and-hay racks are satisfactory, if properly constructed. About 15 to 18 inches of linear feed trough and rack space should be provided for each ewe and 12 to 15 inches for each fattening lamb. Sheep are commonly fed hay and any other feeds twice a day.

EXERCISE IS ESSENTIAL FOR THE EWE FLOCK

If the ewes do not secure plenty of exercise, they are apt to have weak lambs. In winter the ewes may be forced to exercise by scattering roughage over a nearby field. (From Wisconsin Station.)

1292. Wool production.—The composition and structure of wool have been discussed in Chapter X. (314) It has also been there shown that adverse conditions, such as sickness, undue exposure, or a decided lack of feed, will not only

decrease the yield of wool but will also injure the quality.[96]

By proper culling of the flock of breeding ewes and using the weight and quality of the individual fleeces as one basis of selection, a marked improvement can be made in the annual yield of wool.[97] The first year's fleece of a ewe is usually a less reliable index of the fleece weight during succeeding years than the fleece of the second or third year.

The tendency in the case of certain breeds to place undue emphasis on wool covering over the face, ears, and legs is undesirable. A covering of wool around the eyes is a distinct disadvantage, especially under range conditions. Frequent clipping around the eyes is necessary, so that such sheep can see to eat and drink.

Even then, ewes with covered faces are less productive than open-faced ewes. In trials by the United States Department of Agriculture in Idaho, ewes with open faces produced 11 per cent more pounds of lamb a year than those with covered faces.[98] This was in spite of the fact that all ewes that were apt to become wool-blind were clipped around the eyes 3 times a year. The ewes with covered faces produced but a trifle more clean wool a year, only one-twentieth of a pound more, on the average.

Interesting experiments have been conducted in Wyoming to find whether protecting range sheep with canvas coats or rugs during winter would increase the yield or quality of the wool enough to justify the expense.[99] The coats appreciably increased the yield of wool, on the scoured basis, but the life of the coats was too short and the sheep lost too many of them to make the practice profitable.

1293. Shearing sheep.—Sheep are usually shorn in the spring after the weather has become fairly warm and settled. It is unwise to shear them too early, as they need the covering of wool to protect them from cold rains and snows. On the other hand, when shearing is delayed unduly, the sheep suffer from the heat and are troubled more with maggots about the breech, owing to the wool becoming foul.

Sheep should not be shorn when the fleeces are wet or even damp, as the wool is then apt to mildew. The fleeces should always be tied with paper twine or a strand made from the wool. Binder twine or sisal twine should never be used, as the fibers adhere to the wool and cannot be dyed uniformly with the wool. In branding sheep, a scourable branding paint should be used.

In hot climates sheep are often shorn twice a year, so they will be more comfortable. In Texas experiments shearing range ewes twice a year slightly increased the yield of wool, but hardly enough to offset the lower price received for the shorter fleeces.[100] The percentage of lambs born was not increased appreciably by shearing the ewes twice a year, but the death loss was reduced a trifle. Where the range is infested with shrubs like cat's-claw, which tear long wool, shearing twice a year is advisable.

Lambs and sheep that are to be fattened for market are often shorn either before being placed on feed or during the early part of the fattening period, to stimulate their appetites and make them more comfortable. Several experiments have been conducted to compare the results from fattening shorn and unshorn lambs.[101] These tests have shown that unless the weather is so warm that they are uncomfortable, unshorn lambs or other sheep will usually make practically as large and economical gains as if shorn.

In very cold weather shorn lambs may make slower gains and require slightly more feed per 100 lbs. gain. Before shearing, one should find the probable difference in price between fat shorn and unshorn sheep, and also know about how much wool he will secure by shearing and the price it will bring.

QUESTIONS

1. State some of the important advantages of sheep production under farm conditions.
2. Why must some Merino blood be retained in the flocks on the western ranges?

3. Give an example of the improvement that can be made by the use of a purebred ram on common ewes.
4. Why are lambs that are not retained for the breeding flock practically never carried over to the second year?
5. What have experiments shown concerning the importance of good roughage for breeding ewes?
6. Discuss the protein requirements of ewes during various periods.
7. What percentage of protein in a ration (on the air-dry basis) is needed by fattening lambs?
8. Is the quality of protein important for sheep fed good roughage?
9. Discuss the use of urea in feeding sheep.
10. Discuss the addition of a protein supplement to a ration of grain and alfalfa hay for fattening lambs.
11. Should a protein supplement be added to a ration of corn silage, legume hay, and corn or other grain for fattening lambs?
12. Compare the requirements of pregnant ewes and fattening lambs for total digestible nutrients or net energy.
13. What have experiments shown concerning the addition of fat to rations for fattening lambs?
14. What minerals need consideration in feeding sheep under usual conditions?
15. Discuss the salt requirements of sheep.
16. Under what conditions should a calcium supplement be added to sheep rations?
17. Are any trace mineral supplements needed for sheep in your area?
18. Discuss the water needs of sheep.
19. What have experiments shown concerning the use of the following for fattening lambs: (a) Antibiotic feed supplements; (b) arsonic supplements; (c) surfactants; (d) stilbestrol.
20. Discuss: (a) Grinding grain for sheep; (b) chopping or grinding roughage; (c) pelleting feed.
21. Discuss the requirements of sheep for shelter.
22. Compare the requirements of breeding ewes and of fattening lambs for exercise.
23. On what basis would you cull a flock of breeding ewes?
24. Discuss the shearing of sheep and of fattening lambs.

REFERENCES

1. Anderson, Farm Journal, November, 1951.
2. Foster and Hostetler, N.C. Tech. Bul. 60.
3. Horlacher and Good, Ky. Bul. 243; Miss. Sta., mimeo. rpt.; Fleming, Nev. Rpts. 1924, 1925, 1926; Darlow, Okla. Bul. 151; Starkey, S.C. Rpt. 1926; Wilson and Spencer, West Va. Bul. 307.
4. Paterson and Winchester, Kan. Cir. 96; Jones and Dickson, Tex. Bul. 379; see also: Shaw, Mont. Buls. 35, 47, 59.
5. Watson and Fenn, S.D. Bul. 354.
6. Harper et al., Ind. Rpts. 1936, 1937, 1938, 1939, 1940, 1941, 1943, 1944, 1945; Shrewsbury, Harper, Andrews, and Zelle, Ind., Jour. Anim. Sci., 1, 1942, pp. 126–130; Shrewsbury, Harper, and Andrews, Ind., Jour. Anim. Sci., 5, 1946, pp. 47–53; Stitt, Perry, and Beeson, Ind., Jour. Anim. Sci., 13, 1954, pp. 234–241.
7. Pope, Cook, Dinusson, Garrigus, and Weir, National Res. Council, Nutrient Requirements of Domestic Animals, V, Nutrient Requirements of Sheep, 1957.
8. Kammlade, Sheep Science, 1947, p. 248.
9. Klosterman, Buchanan, Bolin, and Bolin, N.D., Jour. Anim. Sci., 10, 1951, pp. 257–265; Klosterman et al., N.D., Jour. Anim. Sci., 12, 1953, pp. 188–200; Richard et al., N.D., Jour. Anim. Sci., 13, 1954, p. 997; Whiting and Slen, Canada, Jour. Anim. Sci., 10, 1951, p. 1067; Slen and Whiting, Canada, Jour. Anim. Sci., 11, 1952, pp. 156–173; Whiting, Slen, and Bezan, Canada, Sci. Agr., 32, 1952, pp. 365–374; Slen and Whiting, Canada, Sci. Agr., 32, 1952, pp. 375–379.
10. VanHorn et al., Mont. Mimeo. Cirs. 56, 62; VanHorn, Payne, Drummond, and Wilson, Mont. Mimeo. Cir. 63; VanHorn et al., Mont. Mimeo. Cir. 70; Mont. Cir. 206; Nash, Whitehair, and Gallup, Okla. Misc. Pub. MP-17; Johnson and Staples, S.D. Bul. 395; Jordan, S.D. Bul. 399; see also: Harper, Ind. Bul. 419; Hunt, Md. Bul. 398.
11. Whitehair, Nash, and Gallup, Okla., Jour. Anim. Sci., 9, 1950, p. 672; Nash, Whitehair, and Gallup, Okla. Misc. Pub. MP-17; see also: Stitt, Perry, and Beeson, Ind., Jour. Anim. Sci., 13, 1954, pp. 234–241; Jordan, Klosterman, and Wilson, S.D., Jour. Anim. Sci., 8, 1949, p. 623.
12. Morrison et al., N.Y., Jour. Anim. Sci., 5, 1946, pp. 408–409; Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834; Willman, Embry, Morrison, and Klosterman, N.Y., mimeo. rpt.; Miller, Morrison, and Briggs, N.Y. (Cornell) Rpts. 1944, 1945; Bush, Willman, and Morrison, N.Y., Jour. Anim. Sci., 14, 1955, pp. 465–469; see also: Pope, Baker, Gallup, and Whitehair, Okla. Misc. Pub. MP-27.
13. Mitchell and Kammlade, Ill. Rpt. 1932.
14. Willman and Morrison, N.Y. (Cornell) Bul. 691; Willman, Klosterman, and Morrison, N.Y. (Cornell) Bul. 834.
15. Willman, Klosterman, and Morrison, N.Y. (Cornell) Bul. 834.
16. Jordan and Peters, Minn. Bul. 306; Alexander and Weber, Nebr., mimeo. rpt.; see also: Bell, Ohio Bul. 532.
17. Esplin, Colo. Farm and Home Res., 4, 1954, No. 6; see also: Esplin, Colo. Farm and Home Res., 3, 1953, No. 6.
18. Slen and Whiting, Canada, Jour. Anim. Sci., 14, 1955, pp. 844–859.
19. Klosterman, Bolin, Lasley, and Dinusson, N.D., Jour. Anim. Sci., 10, 1951, pp. 440–446.
20. Darlow, Heller, and Felton, Okla. Bul. 220.
21. Marston, Australian Council Sci. and Indus., Res. Bul. 61.
22. Harris and Mitchell, Ill., Jour. Nutr., 22, 1941, pp. 183–196; Hamilton, Robinson, and John-

son, Ill., Jour. Anim. Sci., 7, 1948, pp. 26–34; Ellis et al., Mo., Jour. Anim. Sci., 14, 1955, p. 1200; Morrison, Miller, and Maynard, N.Y. (Cornell) Rpts. 1941, 1943; Thomas, Loosli, Williams, and Maynard, N.Y., Jour. Nutr., 43, 1951, pp. 515–523; Briggs, Gallup, Heller, and Darlow, Okla., Jour. Anim. Sci., 7, 1948, pp. 35–40; Gallup, Pope, and Whitehair, Okla., Jour. Anim. Sci., 11, 1952, pp. 621–630.
23. Ill. Rpt. 1938–47; Culbertson and McDonald, Iowa Rpt. 1949; Repp, Hale, and Burroughs, Iowa, Jour. Anim. Sci., 14, 1955, pp. 901–908; Willman, Morrison, and Klosterman, N.Y. (Cornell) Bul. 834; Richard et al., N.D. Bimo. Bul., 17, 1954, No. 1; Gallup, Pope, and Whitehair, Okla. Bul. B-409; Noble, Pope, and Gallup, Okla., Jour. Anim. Sci., 14, 1955, pp. 132–136.
24. Gallup, Pope, and Whitehair, Okla. Bul. B-409; Jordan, S.D. Bul. 429; Mason, Stratton, and Hilston, Wyo. Mimeo. Cir. 32; Slen and Whiting, Canada, Jour. Anim. Sci., 14, 1955, pp. 844–857; Peirce, Australian Jour. Agr. Res., 2, 1951, pp. 435–446; see also: Albert, Garrigus, Forbes, and Hale, Ill., Jour. Anim. Sci., 14, 1955, pp. 143–152.
25. Morton, Osland, and Tom, Colo. Press Bul. 91; Kammlade, Ill. Rpt. 1930; Brown and Blakeslee, Mich. Spec. Bul. 303; Jordan and Peters, Minn. Bul. 306 and mimeo. rpt.; Gramlich, Nebr. Bul. 173 and mimeo. rpt.; Holden, Nebr. Buls. 194, 216; Savin, Nebr. Bul. 197; Fox, Nebr. Buls. 204, 211; Weber, Nebr., mimeo. rpts.; Willman and Morrison, N.Y. (Cornell) Bul. 691; Carmichael and Hammond, Ohio Bul. 245; Darlow, Okla. Buls. 213, 228; Quayle, Wyo. Bul. 191; see also: Bell, Ohio Bul. 695; Johnson and Johnson, S.D. Bul. 373.
26. Miller, Cal., mimeo. rpt.; Maynard, Morton, and Osland, Colo. Bul. 379, Colo. Press Bul. 76; Morton and Fairbanks, Colo. Press Bul. 79; Johnson, Rinehart, and Hickman, Id. Cir. 94, Id. Buls. 194, 229, 269; Jordan and Peters, Minn. Bul. 306; Vinke and Bergstedt, Mont., mimeo. rpt.; Holden, Nebr. Bul. 216; Neale and Bell, New Mex. Bul. 309; Neale and Koger, New Mex. Bul. 335; Wilson, Wright, and Fenn, S.D. Bul. 278 and mimeo. rpt.; Mackey and Jones, Tex. Bul. 465.
27. Coffey, Ill., information to the author; Skinner and King, Ind. Buls. 162, 168; Smith and Mumford, Mich. Bul. 113; Carmichael and Hammond, Ohio Buls. 187, 245; see also: Bell and Edgington, Ohio Bul. 674; Keith, Miller, and Henning, Penn. Bul. 397.
28. Dunn and Evvard, Iowa Bul. 185; Paterson and Winchester, Kan. Cirs. 79, 88; Brown, Mich. Spec. Bul. 233; Brown, Mich. Quar. Bul., 14, 1931, No. 1; Savin, Nebr. Bul. 197; Fox, Nebr. Bul. 211; Holden, Nebr., mimeo. rpt.; Hackedorn, Bean, and Sotola, Wash. Bul. 185.
29. Skinner and King, Ind. Buls. 162, 168, 179, 184; Bell, Ohio, mimeo. rpt.
30. Brown, Mich. Spec. Bul. 233; Johnson, Rinehart, and Hickman, Id. Bul. 176.
31. Miller, Cal., mimeo. rpts.; Maynard, Morton, and Osland, Colo. Bul. 379; Richards and Vinke, Mont. Exten. Cir. 26; Quayle, Wyo. Bul. 191.
32. Kammlade and Butler, Texas Prog. Rpt. 1644.
33. Willman et al., N.Y., mimeo. rpt.
34. Hale and King, Iowa, Jour. Anim. Sci., 14, 1955, p. 1205.
35. Harper, Ind. Rpt. 1938; Evvard, Lamb, and Gaessler, Iowa, Jour. Amer. Vet. Med. Assoc., 67, 1925, N.S. 20, p. 1.
36. Evvard and Culbertson, Iowa Rpts. 1921, 1922, 1923; Cox and Sloan, Kan. Rpt. 1944–46.
37. Evvard et al., Iowa Res. Bul. 94; Jones, Bayles, and Jones, Texas, mimeo. rpt.; Esplin, Madsen, and Phillips, Utah Bul. 292.
38. Evvard et al., Iowa Res. Bul. 94.
39. Bell and Erhart, Kan. Cirs. 273, 283, 297; see also: Hix, Evans, and Underbjerg, Kan., Jour. Anim. Sci., 12, 1953, pp. 459–473.
40. Jardine and Anderson, U.S.D.A. Bul. 790; Sotola, Smith, and Ellington, Wash. Pop. Bul. 127.
41. Potter and Nelson, Western Live Stock Management, p. 146.
42. Weir and Torell, Cal., Jour. Anim. Sci., 12, 1953, pp. 353–358; Meyer and Weir, Cal., Jour. Anim. Sci., 13, 1954, pp. 443–449; Meyer, Weir, and Smith, Cal., Jour. Anim. Sci., 14, 1955, pp. 160–172.
43. Culbertson, Iowa Rpt. 1931; Bell, Ohio Bul. 417 and Ohio Bimo. Bul. 143.
44. Miller, Cal., mimeo rpt.; Morton, Leinbach, and Tom, Colo. Press Bul. 83; Skinner and King, Ind. Buls. 273, 282, 296; Jordan and Peters, Minn., mimeo. rpt.
45. Wyo. Rpt. 1947.
46. Cox and Connell, Kan. Rpts. 1932–34, 1938–40; Alexander, Nebr., mimeo. rpt.; Jones and Stangel, Tex. Bul. 563; see also: Fraps, Tex. Bul. 232.
47. Jordan and Peters, Minn., mimeo. rpt.; Bell, Kick, and Edgington, Ohio Bul. 579.
48. Miller, Cal. Rpt. 1928; Morton and Osland, Colo. Rpt. 1920; Morton, Leinbach, and Tom, Colo. Press Bul. 83; Bell, Ohio, mimeo. rpt.; Bowstead, University of Alberta, Canada, mimeo. rpt.
49. Harper, Ind. Bul. 470.
50. Ewer, British Jour. Nutr., 5, 1951, pp. 287–300.
51. Beeson, Johnson, Bolin, and Hickman, Id. Bul. 266; Beeson et al., Id. Bul. 268; Keith, Melendy, and Johnson, Id. Res. Bul. 29.
52. Beeson, Johnson, Bolin, and Hickman, Jour. Anim. Sci., 3, 1944, pp. 63–70; Id. Buls. 220, 225, 229, 236, 239, 244, 255.
53. Briggs, Gallup, Pope, and Whitehair, Okla. Misc. Pub. MP-17; Gallup and Briggs, Okla., Jour. Anim. Sci., 9, 1950, pp. 426–430.
54. Ill. Rpt. 1938–47.
55. Knox and Watkins, New Mex. Bul. 287; Utah Buls. 306, 343; see also: Miller, Hart, and Cole, Cal. Bul. 672; N.C. Rpt. 1941.
56. Colo. Rpt. 63; Esplin, Colo. Farm and Home Res., 3, 1953, No. 6; Ill. Rpt. 1938–47; Ky. Rpts. 64, 65, 66; Klosterman, N.D. Bul. 371; Jordan and Weakly, S.D. Bul. 425; Rpt. of Chief, Bur. Anim. Indus., U.S.D.A., 1949.
57. Pope, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 6, 1947, pp. 334–342; Richard et al., Wis., Jour. Anim. Sci., 13, 1954, pp. 694–705.
58. Smith, Becker, Loosli, and Beeson, N.Y., Jour. Anim. Sci., 9, 1950, pp. 221–230.
59. Willman, Embry, and Morrison, N.Y., (Cornell) Rpt. 1950 and mimeo. rpt.
60. Miller, Hart, and Cole, Cal. Bul. 672; Hart and Miller, Cal., Jour. Agr. Res., 55, 1937, pp. 47–58; Eveleth, Bolin, and Goldsby, N.D., Amer. Jour. Vet. Res., 10, 1949, pp. 250–255; Colby, Cunha, and Warwick, Wash., Jour. Anim. Sci., 9, 1950, pp. 446–456; Pope, Phillips, and Bohstedt, Wis.,

Jour. Anim. Sci., 8, 1949, pp. 57–66; Weir, Pope, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 8, 1949, pp. 381–391.
61. Ill. Rpt. 1938–47.
62. Fitch and Ewer, Australian Vet. Jour., 20, 1944, pp. 220–226; Andrews and Cunningham, New Zealand Jour. Sci. and Tech., 27, 1945, No. 3, Sect. A, pp. 223–230.
63. McIlroy and Goss, Cal., Jour. Nutr., 20, 1940, pp. 527–550; 21, 1941, pp. 163–173, 405–409; Miller, Hart, and Cole, Cal. Bul. 672; Pearson, Winegar, and Schmidt, Tex., Jour. Nutr., 20, 1940, pp. 551–563.
64. Pope, Richard, and Phillips, Wis. Bul. 492.
65. Draper and Johnson, Ill., Jour. Nutr., 43, 1951, pp. 413–422; 46, 1952, pp. 123–131; Luecke et al., Mich., Jour. Anim. Sci., 9, 1950, pp. 420–425.
66. Pontius, Carr, and Doyle, Ind., Amer. Soc. Anim. Prod., Proc. 1931; Evvard et al., Iowa Bul. 234; F. B. Mumford, Mich. Buls. 113, 128; H. W. Mumford, Mich. Bul. 136; Plumb, Ohio, Amer. Soc. Anim. Prod., Proc. 1925–26; Ore. Rpt. 1926–28.
67. Hatfield, Garrigus, and Norton, Ill., Jour. Anim. Sci., 13, 1954, pp. 715–725; Culbertson et al., Iowa A.H. Leaflet 181; Culbertson, Iowa, Farm Journal, April, 1954; Bell and Erhart, Kan. Cir. 308; Jordan, Jordan, and Croom, Minn., Jour. Anim. Sci., 15, 1956, pp. 188–192; Bohman, Hunter, and Walker, Nev., Jour. Anim. Sci., 14, 1955, pp. 111–117; Klosterman, Dinusson, Light, and Buchanan, N.D. Bimo. Bul., 14, 1951, No. 2; Richard and Dinusson, N.D. Bimo. Bul., 16, 1954, No. 3; Tillman and MacVicar, Okla., Jour. Anim. Sci., 12, 1953, pp. 955–966; Jordan, S.D., Jour. Anim. Sci., 11, 1952, pp. 566–571; 13, 1954, p. 1009; Colby, Rau, and Dunn, Texas, Proc. Soc. Exptl. Biol. Med., 75, 1950, p. 234; Colby, Rau, and Couch, Texas, Amer. Jour. Physiol., 163, 1950, p. 418; Packett, Bridges, Hoelcher, and Kunkel, Texas, Jour. Anim. Sci., 14, 1955, pp. 1219–1220; Botkin and Paules, Wyo. Mimeo. Cirs. 33, 44; Elliott and Ellsworth, Jour. Anim. Sci., 12, 1953, p. 914.
68. Evans, Grainger, and Thompson, Ky., Jour. Anim. Sci., 14, 1955, p. 1202; Turner and Hodgetts, Australian Jour. Agr. Res., 3, 1952, pp. 453–459; see also: Tillman and MacVicar, Okla., Jour. Anim. Sci., 15, 1956, pp. 211–217.
69. Hatfield, Garrigus, and Norton, Ill., Jour. Anim. Sci., 13, 1954, pp. 715–725; Jordan, S.D., Jour. Anim. Sci., 11, 1952, pp. 566–571; Packett, Bridges, Hoelcher, and Kunkel, Texas, Jour. Anim. Sci., 14, 1955, pp. 1219–1220; Johnson, Elliott, and Shor, Jour. Anim. Sci., 14, 1955, p. 1211.
70. Beeson, Perry, Stitt, and Outhouse, Ind., Jour. Anim. Sci., 13, 1954, pp. 242–244; Jordan and Bell, S.D. and Kan., Jour. Anim. Sci., 10, 1951, p. 1051; 13, 1954, pp. 450–454; Kinsman and Riddell, Vt., Jour. Anim. Sci., 11, 1952, p. 769; Moinuddin, Pope, Phillips, and Bohstedt, Wis. Bul. 509.
71. Bucy et al., Ill., Jour. Anim. Sci., 13, 1954, pp. 668–676; 14, 1955, pp. 435–445.
72. Jordan, S.D., Jour. Anim. Sci., 12, 1953, p. 922.
73. Clegg, Albaugh, Lucas, and Weir, Cal., Jour. Anim. Sci., 14, 1955, pp. 178–185; Means, Andrews, and Beeson, Ind., Jour. Anim. Sci., 12, 1953, pp. 176–181; Andrews and Beeson, Ind., Jour. Anim. Sci., 12, 1953, pp. 182–187; Culbertson et al., Iowa A.H. Leaflet 181; Bell and Erhart, Kan. Cirs. 297, 308; Bell, Smith, Erhart and Holland, Kan., Jour. Anim. Sci., 13, 1954, pp. 966–967; Galloway, Bratzler, Blakeslee, and Meites, Mich. Quar. Bul., 35, 1952, No. 1; Jordan, Minn., Feed Age, November, 1952; Richard and Dinusson, N.D. Bimo. Bul., 16, 1954, No. 3; Acker, Whiteman, Gallup, and Tillman, Okla. Misc. Pub. MP-43; Jordan, S.D., Jour. Anim. Sci., 12, 1953, pp. 670–683, 948; Murphree, Cannon, Odom, and Hobbs, Tenn., Jour. Anim. Sci., 13, 1954, p. 1027; O'Mary et al., Wis., Jour. Anim. Sci., 11, 1952, pp. 656–673; Wilkinson et al., Wis., Jour. Anim. Sci., 14, 1955, pp. 866–877; Whiting, Clark, and Allen, Canadian Jour. Agr. Sci., 34, 1954, pp. 288–290; Stephens and Thompson, Tasmanian Jour. Agr., 23, 1952, pp. 291–297.
74. Henneman, Rust, and Meites, Mich., Jour. Anim. Sci., 12, 1953, p. 947; Jordan, Jordan, and Croom, Minn., Jour. Anim. Sci., 14, 1955, pp. 936–940; Wilkinson, Carter, and Copenhaver, Va., Jour. Anim. Sci., 14, 1955, p. 1260.
75. Luther et al., Jour. Anim. Sci., 13, 1954, p. 1025.
76. Hale, Homeyer, Culbertson, and Burroughs, Iowa, Jour. Anim. Sci., 14, 1955, pp. 909–918.
77. Smith, Bell, Erhart, and Mackintosh, Kan., Jour. Anim. Sci., 14, 1955, pp. 1256–1257.
78. Jordan, Jordan, and Croom, Minn., Jour. Anim. Sci., 14, 1955, pp. 936–940, mimeo rpts.
79. Bell, Taylor, Murphree, and Hobbs, Tenn., Jour. Anim. Sci., 14, 1955, p. 1194.
80. Willey, Jones, and Lyerly, Texas Bul. 733.
81. Toevs and Hickman, Id. Bul. 251; Kammlade, Ill. Rpt. 1935; Harper, Ind. Bul. 470; Culbertson, Iowa Rpt. 1943, Part 1; Brown and Blakeslee, Mich. Spec. Bul. 303; Jordan and Peters, Minn., mimeo. rpt.; Nebr. Rpt. 1938; Fleming and Young, Nev. Rpt. 1940; Neale and Bell, New Mex. Bul. 309; Willman and Morrison, N.Y. (Cornell) Rpt. 1936; Darlow, Okla. Bul. 228; Heller, Wall, and Briggs, Okla. Tech. Bul. 10; Ore. Bul. 350; Richards, Ore. Bul. 370; Quayle, Wyo. Bul. 243; see also: Dowe and Klosterman, S.D. Rpt. 1948; McCarty and Weakly, S.D. Rpt. 1950.
82. Weber and Fox, Nebr. Bul. 259.
83. Miller, Cal. Rpt. 1923; Carlyle and Morton, Colo. Bul. 151; Morton, Colo. Bul. 187; Hickman, Rinehart, and Johnson, Id. Buls. 135, 194 and Id. Cir. 19; Potter, Ore., information to the author; Darlow, Okla., mimeo. rpt.; Hackedorn, Singleton, and Sotola, Wash. Bul. 351.
84. Scott, Ariz., mimeo. rpt.; Potter, Ore., information to the author; Morton, Colo. Bul. 187; Johnson, Rinehart, and Hickman, Id. Bul. 177, Cir. 19; Hackedorn, Singleton, and Sotola, Wash. Bul. 351; see also: Quayle, Wyo. Bul. 191.
85. Mackey and Jones, Tex., mimeo. rpt.; Colo. Rpt. 1934; Darlow, Okla. Bul. 213.
86. Cate et al., Ill., Jour. Anim. Sci., 14, 1955, pp. 137–142; Bell, Richardson, Hughes, and Parrish, Kan. Cir. 308; Bell, Erhart, and Richardson, Kan., Jour. Anim. Sci., 14, 1955, p. 1194; Jordan, Minn., mimeo. rpt.; Thomas, VanHorn, Aasheim, and Hoversland, Mont., Jour. Anim. Sci., 14, 1955, pp.

1223–1234, and Mont. Mimeo. Cir. 80; Noble et al., Okla. Misc. Pubs. MP-31, MP-34; Jordan, S.D., Jour. Anim. Sci., 13, 1954, p. 1009; Schneider, Luce, and Goodwin, Wash., Jour. Anim. Sci., 12, 1953, pp. 930–931; Lindahl, U.S.D.A., Agr. Res., 3, 1955, No 12; see also: Long, Nelson, and MacVicar, Okla., Jour. Anim. Sci., 14, 1955, pp. 947–950.

87. Neale, New Mex. Bul. 375; see also: Cate et al., Ill., Jour. Anim. Sci., 14, 1955, pp. 137–142.
88. Esplin, Colo. Farm and Home Res., 1, 1951, No. 6; Bell, Richardson, Hughes, and Parrish, Kan. Cir., 308; Thomas, VanHorn, and Aasheim, Mont. Mimeo. Cir. 80.
89. Cox, Hughes, and Parrish, Kan. Rpt. 1948–50; Bell, Cox, and Hughes, Kan. Cirs. 273, 283; Nebr. Sta., mimeo. rpt.
90. Skinner and King, Ind. Buls. 168, 179, 184, 192, and 202.
91. Morrison and Kleinheinz, Wis. Bul. 323, and unpublished data.
92. Gramlich, Nebr. Bul. 173; Johnson, Rinehart, and Hickman, Id. Buls. 176, 205, and mimeo. rpts.
93. Withycombe and Potter, Ore. Bul. 175.
94. Mumford, Trowbridge, and Hackedorn, Mo. Bul. 115.
95. Willman and Morrison, N.Y. (Cornell) Bul. 691.
96. N. Mex. Rpt. 63.
97. Lindgren, Ore., mimeo. rpt.; Lush and Jones, Tex. Bul. 311; Hill, Wyo. Bul. 127; Burns, Wyo. Bul. 285.
98. Terrill, U.S.D.A., Jour. Anim. Sci., 8, 1949, pp. 352–361.
99. Burns and Johnson, Wyo. Bul. 298.
100. Jones, Davis, and Dameron, Tex., Amer. Soc. Anim. Prod., Proc. 1937; see also: Leveck, Miss. Inform. Sheet 412; Fletcher and Reid, Miss., Jour. Anim. Sci., 12, 1953, pp. 666–669.
101. Stanley and Scott, Ariz. Rpt. 1932; Rinehart, Hickman, and Johnson, Id. Bul. 194; Coffey, Ill. Bul. 167; Ill. Rpt. 1938–47; Culbertson, Iowa Rpt. 1946, Part 1; Skinner, King, and Starr, Ind. Buls. 168, 202, 221; Harper, Ind. Bul. 427; Ky. Rpts. 1941, 1943; Mumford, Mich. Bul. 128; Jordan and Peters, Minn. Farm and Home Sci., 1, 1944, No. 3; Dyer, Mo., Jour. Anim. Sci., 9, 1950, p. 674; Gramlich, Nebr. Buls. 167, 170; Fox, Nebr. Bul. 204; Willman, Klosterman, and Morrison, N.Y. (Cornell) Bul. 834; N.C. Res. and Farming, 1, 1943, Prog. Rpt. 2; Ore. Bul. 350; Keith and Henning, Penn. Bul. 357; Craig, Wis. Rpt. 1904.

CHAPTER XXXI

FEEDING AND CARING FOR SHEEP AND LAMBS—FATTENING LAMBS—GOATS

I. The Breeding Flock; Raising the Lambs

1294. Essentials of successful flock management.—Intelligent management and proper care are even more necessary for success in sheep production than with the other classes of livestock. Yet, sheep are not hard to raise, once their relatively simple requirements are understood. Some of the most important points in successful flock management are: (1) Plenty of good pasture throughout the growing season; (2) proper feed and care of the ewes during winter, before and after lambing; (3) control of parasites; (4) producing the kinds of lambs that are in demand and having the lambs ready for market at the time of year when prices are high.

Order, regularity, and quiet are of prime importance in the management of sheep. The flock should always be cared for by the same attendant, who moves among them quietly, giving notice of his approach by speaking in a low voice and closing doors and gates gently. Cleanliness is essential, for sheep are fastidious, and dislike eating from dirty feed racks or troughs.

Unless stated otherwise, the discussions in this chapter concerning the feeding and care of sheep apply mainly to flocks kept under farm conditions. The production of sheep on the range is considered later in the chapter. (1325) Finally, the fattening of feeder lambs, especially those from the western ranges, is discussed in some detail. (1326–1337)

1295. Importance of good pasture.—For efficiency and economy in sheep production, an abundance of good pasture is essential for the flock throughout the growing season. Good pasturage is not only very important in keeping sheep thrifty, but also it is far cheaper than harvested feeds.

The economy of pasture is well shown by Indiana experiments with ewes and lambs, conducted during 3 pasture seasons.[1] Unweaned lambs made larger gains and reached better market finish when on good pasture with their mothers, without grain feeding, than when the ewes were fed in a dry lot, without pasture, on an excellent ration of alfalfa hay, corn, and oats. This was true even when the lambs in the dry lot were fed plenty of corn and alfalfa hay in a lamb creep. The cost of feed eaten by lambs and ewes, for each 100 lbs. gain made by the lambs, was only $2.83 for the lambs on pasture, in comparison with $16.82 for those in the dry lot.

1296. Pastures for sheep.—Permanent pastures or fields in the regular crop rotation are used most commonly for farm flocks of sheep. This is because such pastures generally provide forage at lower cost and over a longer season than annual pasture crops like rape or Sudan grass. Temporary pasture crops may be very useful in furnishing forage when other pastures are scanty during midsummer drouth. However, good pasture for this period can often be provided most readily and economically by using for pasture the second growth of mixed legumes and grasses on an early-cut hay field. (382)

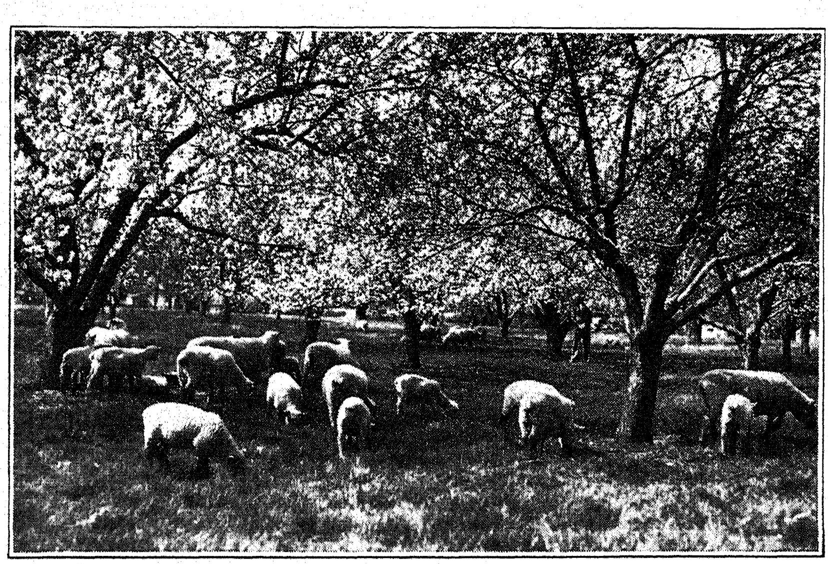
Detailed information has been presented in Chapter XIII on the fertilization, improvement, and management of pastures. The various pasture crops adapted to different regions have been discussed in Chapters XVI, XVIII, and XIX. It has been emphasized in these chapters that in most humid regions suitable mixtures of legumes and grasses are far superior to grass alone for pasture.

Such mixtures provide more nutritious forage than grass alone. Even more important, they furnish good feed over a longer period, especially in midsummer when such a grass as Kentucky bluegrass makes little growth.

Among the high-yielding pasture mixtures are alfalfa with bromegrass or timothy, Ladino clover and grass, or lespedeza and grass. The superiority of such mixtures over grass alone for sheep pasture is well shown by Michigan and Illinois tests.[2] In 3 Michigan trials the average liveweight gain of sheep per season was 362 lbs. per acre on alfalfa-bromegrass pasture and 309 lbs. on alfalfa-orchard grass pasture, in comparison with only 54 lbs. on orchard grass alone. In the Illinois tests the gain per acre on alfalfa-bromegrass over a 5-year period was nearly twice as great as on bromegrass alone.

Mixtures of alfalfa or clover with grass provide much safer pasture for sheep than the legumes alone, because there is far less danger from bloat. Nevertheless, in pasturing such mixtures, the precautions emphasized before should always be taken. (49) Even with proper care, animals occasionally bloat, especially on sultry days following a rain. Immediate attention is then necessary to save the afflicted animals. One of the methods of treatment suggested later should then be used. (1298)

The pasture season can often be extended by using winter grain for pasture in late fall and early spring. In the southern states, winter grain or other winter pasture crops will furnish good pasture during most of the winter.



Good Pasture Essential Throughout the Season

For efficiency and economy in sheep production, an abundance of good pasture is essential from early in the spring until late in the fall.

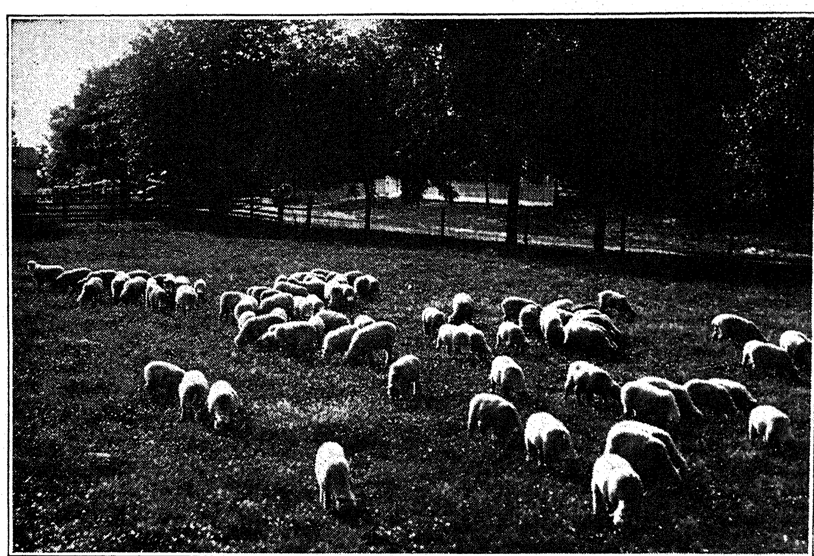
The importance of such pasture for early lamb production is shown by Georgia tests.[3] Lambs pastured with their dams on wheat pasture gained 60 per cent faster, to weaning time, than did lambs on permanent pasture. The use of such clean temporary pasture is also important in helping to prevent trouble from internal parasites.

1297. Pasture management for sheep.—Instead of keeping the sheep on one large pasture for the entire season, it is much better to divide the area into fields of such size that the sheep can be changed from one to another at frequent

intervals, after they have grazed an area thoroughly. This will reduce the trouble from internal parasites, and it will also utilize the pasture more fully, since rotational grazing tends to increase the yield of forage. (376) Rotational grazing is especially advantageous with such pasture combinations as alfalfa and bromegrass, or Ladino clover and grass.

As sheep relish most weeds and browse eagerly on sprouts and brush refused by other stock, small farm flocks will help protect them from dogs. Shade should be provided in the pasture. If there are no trees, a cheap movable shade should be made. This should be placed on the poorer spots in the field, so the droppings of the sheep will enrich them.

1298. Treatments for bloat.—If the bloating is not too severe, a drench of not to exceed a tablespoonful of formalin or of bicarbonate of soda in half a pint of warm water may be given to stop the gas production.[4] Sometimes a pint to a



Mixed Legume and Grass Pastures Are Ideal for Sheep

There is far less danger from bloat on mixed legume-and-grass pasture than on legumes alone.

can glean much feed from such sources and at the same time help in cleaning up the farm, especially lanes and fence corners. The wise flockmaster will always fully utilize all such feed, including stubble and stalk fields and the aftermath on meadows, thus reducing the cost of feed. Sheep prefer reasonably short grass to rank growths, and will eat weeds much better while they are young.

It is a good plan to have the pastures so located that the sheep can return to the barn for night shelter. It is then easier to inspect the sheep daily so that any trouble may be discovered, and it quart of warm milk is administered instead. Another treatment is to fasten a stick in the sheep's mouth, like a bit, by a cord tied back of the head. Chewing on the stick tends to cause belching, and enables the animal to get rid of the gas.

Severe bloat can sometimes be relieved by forcing a piece of one-half inch or smaller hose down the animal's gullet and into the rumen, to let the gas escape. As a last resort, a trocar or small knife should be used to tap the rumen.

1299. The ewe flock.—Profits from sheep depend largely upon having a flock of ewes that are carefully selected and

properly culled. The ewes should be healthy and vigorous, with deep, wide, roomy bodies, good teeth, sound udders, and high-quality, dense fleeces. They should be good milk producers and also be of good size for their breed, for under-sized ewes produce less wool and less weight of lambs per year.[5] However, they should not be too large or coarse, or their lambs may be too large to meet the market demands, before they are fat enough for slaughter. Per 100 lbs. of liveweight, small ewes may produce as much or more weight of lambs and wool as do larger ones, though their production per head is lower.[6]

Before the breeding season in the fall, the flock should be carefully culled, and all ewes discarded which are non-breeders or poor milkers, or which are otherwise unprofitable. These should be replaced by the most promising individuals raised in the flock. The ewes retained should not be selected by looks alone, for the thinnest ones may have been brought to this condition by a heavy milk flow. The only efficient method of selection is to keep a simple flock record, in which are recorded the ear-tag or ear-notch number of each ewe, the weight of fleece produced, the number of lambs raised, and the weight of the lambs at weaning time or when marketed. As a rule, good ewes should be retained as long as they are productive. In farm flocks most of the ewes are disposed of when 6 to 7 years of age.

Although well-grown ewe lambs will usually come in heat at 6 to 9 months of age, most sheepmen prefer to postpone breeding for a year, so that the ewes will have their first lambs when about 2 years old. Experiments have shown, however, that under favorable farm conditions a partial extra lamb crop can be secured by breeding ewe lambs of the earlier-maturing mutton breeds, if they are well grown and fed liberally.[7] Only a 60 to 70 per cent lamb crop will usually be secured the first year from ewes bred as lambs, and their lambs will not be so thrifty or so large at weaning time as lambs from older ewes.

Ewes bred as lambs generally reach the same size as those first bred as yearlings, but they are slower in maturing. In later gestations they produce as many and as large lambs as ewes first bred as yearlings. At 5 or 6 years of age the ewes bred as lambs will usually have raised an appreciably greater total weight of lambs. Breeding ewe lambs is not advisable in purebred flocks or under range conditions.

1300. Date of lambing; gestation period.—To secure the best prices for farm-raised fat lambs, they should be ready for market either before or after the rush of grass-fat lambs from the western range states. If warm quarters and plenty of good legume hay and grain are available, early lambs, dropped before April first and marketed not later than July, are usually most profitable, for they commonly sell at a higher price per hundredweight than later lambs. Such lambs are less troubled with internal parasites, and another advantage is that the lambing season comes before the rush of spring work.

Ewes which lamb early need plenty of good feed in winter and the lambs should be fed grain before pasture is available in the spring. The production of "spring lambs" and of "hot-house lambs" is discussed later in this chapter.

Where grain and good hay are expensive or if the shelter is not suitable for early lambs, it is best to have the lambs born in April or May and to sell them in autumn after the rush of western lambs to market.

The average length of the gestation period of ewes is 145 to 147 days, according to various authorities.[8] It is longer for Merino and Rambouillet ewes than for ewes of the mutton breeds, averaging about 152 days for the former breeds. For Southdowns and Shropshires, it is usually slightly shorter than for the larger mutton breeds.

1301. Twin lambs.—Under favorable conditions where good care can be given to the ewes and lambs, it is important to secure a high lambing percentage. To obtain this, a large proportion of the ewes must have twin lambs.

Twin lambs will generally gain less

than singles while nursing, as they get less milk. However, they tend to make up some of the difference later, if they have good pasture.

In Ohio studies, an average of 198 lbs. in market weight of lambs was secured from ewes raising twin lambs, in comparison with 104 lbs. for ewes with singles.[9] This shows that twins are certainly advantageous under favorable farm conditions.

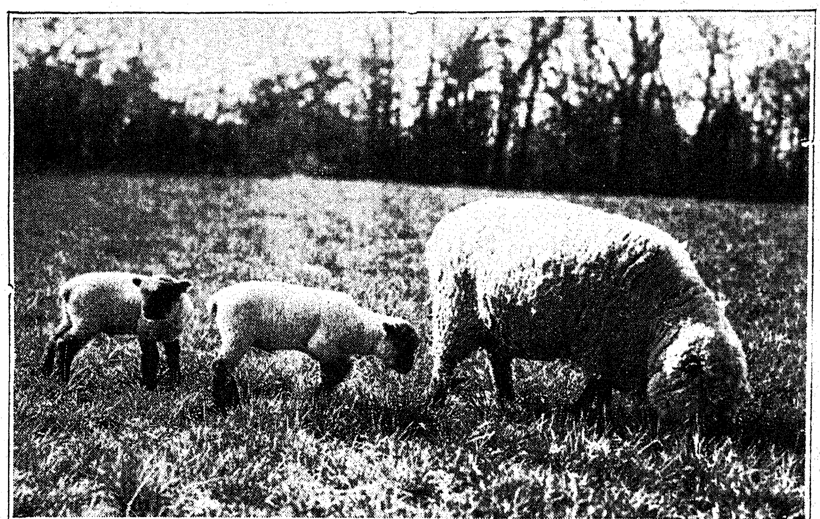
On the western ranges, where less attention can be given to the individual ewes, single lambs have usually been preferred. However, experiments show that even under range conditions, twin lambs are desirable if pasture and feed conditions are average or better, except for aged or for immature ewes.[10] A decidedly larger average total weight of lambs was produced by ewes with twins, than by ewes having single lambs.

1302. Breeding time; flushing the ewes.—The natural breeding season for most breeds of sheep is during the late summer and autumn. Ewes will usually begin to come in heat after the first cool nights, and the periods of heat recur approximately every 16 days, unless the ewes conceive.

It is a common belief among experienced sheepmen that ewes which are "flushed" at breeding time, or fed so that they are gaining in weight, are more apt to produce twins and triplets than those which are in poor flesh, and that they also breed earlier and more nearly at the same time. In most, but not all, of the experiments to study the effect of flushing ewes, the practice has proved decidedly beneficial.[11]

Any advantage of flushing can undoubtedly be gained by furnishing the ewes with excellent pasture previous to and during the breeding season. If such pasture cannot be provided, it may be well to feed them a small amount of grain at this time. Liberal feeding before breeding time is especially needed if the ewes have run down in flesh during summer, as is common with ewes having large milk flows, even though they have had good pasture. If ewes have been fed inadequately after their lambs were weaned, and have consequently run down in condition, many of them will fail to come in heat or they may fail to conceive.

Attempts to secure earlier lambs by injecting hormones into ewes have usu-



Twin Lambs Most Profitable under Favorable Conditions

If the ewes and lambs are well fed, twin lambs will gain nearly as rapidly as single lambs.

ally not been successful.[12] Where such treatment has brought ewes into heat, in most cases they have not become pregnant when bred.

In a Kentucky experiment ewes kept at a cool temperature in an air-conditioned room in summer, bred nearly 8 weeks earlier than those not so housed.[13] This indicates that where one wishes to produce early lambs, it may help to have plenty of shade in the pasture for the ewes in summer, and a cool, well-ventilated barn for night shelter.

Whether the shorter days in the fall are of importance in bringing ewes into heat, seems to be an unsettled question. The results of experiments on length of day have differed.[14]

1303. The ram.—A well-built, vigorous purebred ram of good breeding should be selected for the flock, and then be so fed and cared for that he will remain potent. A vigorous ram will serve 40 to 50 ewes a season, if allowed to run with them all the time during the breeding season, as is the common practice. Where "hand coupling" is practiced or if the ram is turned with the ewes only a short time daily, more ewes can be bred to one ram. A well-grown ram lamb may be bred to 12 or 15 ewes without reducing his future usefulness, if he is properly fed and handled.

During most of the year good roughage alone should be sufficient to keep the ram in proper condition. Pasture should be provided in summer, if possible. In winter he should be fed legume or mixed hay, and perhaps silage in addition. Mangels or sugar beets should not be fed, as they may tend to produce urinary calculi, or stones. (632)

For a month before the breeding season, the ram should be given about a pound a day of the same sort of concentrate mixture that is fed the ewes. It is also a good plan to continue the feeding of the concentrate allowance during the breeding season, if it can be done conveniently. The ram should not be allowed to run down seriously at breeding time through insufficient feed or over use. On the other hand, he should never become fat. In purchasing a ram, one that has been highly fitted, or fattened, for shows should be avoided, for over-fitting may result in low fertility.

It is a good plan to keep the ram away from the ewes, except during the breeding season, so that he cannot annoy them. However, he needs exercise to keep in vigorous condition. If a pasture paddock is not provided for him, it is better to let him run with the flock throughout the year than to confine him.

The fertility of rams may be lowered by very hot weather.[15] Where early lambs are desired, it may be desirable to keep rams as cool as possible by shearing them 3 or 4 weeks before the breeding season.

1304. Feeding the ewes in the fall.—Plenty of good pasturage should be provided for the ewes in the fall. Where the weather is mild, considerable of their late fall and winter feed can come from winter rye or wheat pasture or from grass pasture which has been allowed to grow up in the fall.

Ewes can often get much of their fall feed by cleaning up stalk and stubble fields, thus using feed that would otherwise be wasted. It is best to use such forage early, before fall rains and frost have lessened its value, and to leave other pasture for later grazing. If there is a shortage of pasture in the fall, care should be taken to supply sufficient hay or grain to keep the ewes thrifty. Rape furnishes excellent feed late in the fall.

1305. Winter feed and care.—If the ewes go into the winter in thrifty condition and are then fed as much good legume or mixed legume-grass hay as they will eat, with or without silage or roots in addition, they will usually need no grain or other concentrates until 4 to 6 weeks before lambing. Then not more than 0.50 to 0.75 lb. per head daily is commonly required, and the ewes should not be allowed to become really fat. An experienced shepherd knows that the only safe way to determine the condition of a sheep is by feeling of its back. If he finds that the ewes are not thriving, he will feed them more liberally.

The ewes should be wintered so that they will gain 20 to 30 lbs. during preg-

nancy, and be in medium flesh and vigorous condition at lambing time. Experiments have shown that insufficient feed or an unbalanced ration, especially during the latter part of pregnancy, often results in weak lambs and a scanty flow of milk.[16] Ewes that are seriously underfed at this time may show but little mothering instinct when their lambs are born, and may have very little milk for them.

On the other hand, it is not only unnecessarily expensive but also unwise to feed breeding ewes so liberally that they are really fat at lambing time.[17] They are then apt to have more difficulty in lambing and may also produce weak lambs.

Both ram lambs and ewe lambs intended for the breeding flock should be so fed the first winter that they will grow steadily, but they should never receive a fattening ration.

For winter shelter, dry, well-ventilated quarters should be provided, with wide doorways and convenient feed racks. (**1289, 1291**) It is best to divide large flocks into groups of sheep of similar size and condition, so that the amount of feed can be suited to the needs of each group. For example, yearling ewes will need a little more feed than mature ewes, as they are still growing. Exercise in winter is essential for breeding ewes, as has been emphasized previously. (**1290**) Salt and plenty of water should always be provided for the flock.

1306. Rations for ewes.—As a guide in selecting satisfactory and economical balanced rations for breeding ewes, several example rations that are adapted to conditions in various sections are given in Appendix Table VII. These are balanced according to the Morrison feeding standards, and should produce satisfactory results. Ewes wintered in the open in the northern range states, without shelter, may require somewhat larger amounts of feed than stated, due to the exposure.

The amounts of roughage stated in these rations are the amounts actually eaten, after deducting the wastage.

1307. Hay, silage, and other roughages for ewes.—The importance of high-quality hay and other good roughage in wintering pregnant ewes has been emphasized in the previous chapter. (**1264**) The lamb crop is apt to be very unsatisfactory if most of the roughage for the ewes is straw or low-grade hay. Detailed information is given in Part II concerning the value for sheep of the various kinds of hay and other roughages.

If possible, the ewes should be fed a liberal amount of good legume hay or mixed hay high in legumes. Such hay is rich not only in protein, calcium, and vitamins, but it is also laxative. Moreover, it is usually more economical to supply the necessary protein for the ewes by feeding legume hay than by purchasing considerable amounts of protein supplements.

For sheep, grass hay is best used along with some legume hay. In South Dakota experiments the results in wintering ewes were as satisfactory with about 1 lb. of alfalfa hay per head daily plus what good bromegrass or wheatgrass hay they would eat, as on alfalfa hay as the only roughage.[18] The feed cost was less on the combinations.

Late-cut grass hay is unsatisfactory for sheep, for it is not only unpalatable and low in nutrients, but also it may cause serious constipation. Early-cut and well-cured grass hay, though inferior to legume hay, may be used satisfactorily as the only roughage, when properly supplemented with protein and minerals. (**566**) Well-cured corn or sorghum fodder, harvested while the leaves are still green, is preferable to late-cut grass hay. Straw alone or straw with corn silage or sorghum silage is unsatisfactory as the roughage for ewes.

Corn silage, sorghum silage, or hay-crop silage is an excellent addition to a ration for wintering ewes. It aids in preventing constipation and in keeping the ewes thrifty, especially when little or no legume hay is available. Adding silage to an abundance of good alfalfa hay does not usually make much difference in the thrift of the ewes or the vigor of the lambs. The economy of using silage under such conditions will depend on the relative cost of silage and of alfalfa hay,

good corn silage being worth about one-half as much per ton as such hay. Though roots are excellent for ewes, silage is a much more economical feed under conditions in the United States.

It is best to use corn or sorghum silage along with good legume or mixed hay, instead of feeding it as the only roughage.[19] A good plan is to feed at least 1 lb. of hay to each 2 to 3 lbs. of silage. However, corn silage has even been satisfactory as the only roughage for pregnant ewes, when a sufficient amount of protein supplement has been fed and also a calcium supplement.[20]

Hay-crop silage of good quality is also satisfactory as the only roughage for ewes. (**440**) Because of the lack of grain in such silage, it may be necessary to feed a little grain, in order to keep the ewes in the desired condition. However, no protein supplement is needed with hay-crop silage.

In the southern states special winter pasture crops can furnish much of the feed for ewes and early lambs. In 3 Mississippi trials the average net return per ewe was $11.20 for ewes wintered chiefly on temporary pastures, in comparison with $6.12 for ewes in dry lot.[21] In Missouri trials with ewes bred for early lambs and wintered on good pasture plus hay when the weather did not permit grazing, it did not pay to feed concentrates previous to lambing.[22]

1308. Concentrates for ewes.—Not only the amount but also the kind of concentrates required by breeding ewes will depend on the kind of roughage that is used. If a liberal amount of legume hay is fed, the concentrates may be chiefly or entirely grains, such as oats, corn, barley, or the grain sorghums.

Oats are highly esteemed as a feed for ewes and are often fed as the only concentrate with legume hay. Corn is considered too fattening by many shepherds to be used as the chief concentrate. They prefer bulky mixtures containing considerable oats or wheat bran. However, if plenty of protein is furnished by legume hay or other protein-rich feeds and the ewes are not over-fed on corn so that they become unduly fat, corn can be used satisfactorily as the chief or only grain.[23] Because corn is higher than oats in total digestible nutrients and net energy, less corn than oats is needed to keep the ewes in suitable condition.

Barley, wheat, and the grain sorghums are all satisfactory for breeding ewes, when fed in suitable mixtures.

Unless a liberal amount of legume hay is fed to the ewes, it will be necessary to include a sufficient amount of a protein supplement in the concentrate or grain mixture to balance the ration. Several concentrate mixtures that are suitable for feeding with various combinations of roughage are given in Appendix Table VII. The values of the various protein supplements have been discussed in chapters of Part II. Wheat bran and linseed meal are probably most widely used for the breeding flock in the United States, but other supplements are satisfactory when they are more economical. If there has been trouble from the "stiff lamb disease" in the flock, it is important to include wheat bran or wheat germ meal in the concentrate mixture for the ewes and the lambs. (**1315**)

Under usual conditions it is most economical to winter ewes on all the roughage they will eat, with only enough concentrates to keep them in proper condition. When hay is high in price in comparison with grain, it may be economical to restrict somewhat the amount of hay fed to ewes, and to increase the allowance of grain or other concentrates instead. Judging from the results of Kentucky, Michigan, and Montana trials, 100 lbs. of grain will replace 175 to 200 lbs. of hay when thus fed.[24]

If ewes are fed good roughage, there is no advantage in adding a vitamin A or carotene supplement to the winter ration.[25] (**1281**)

1309. Supplementing winter range.—Where ewes are wintered on mature and weathered range forage, experiments have shown that the feeding of a suitable supplement will usually be profitable. It will keep the ewes in thrifty condition, will bring a greater lamb crop, will increase the weights of the lambs at

birth and at weaning, and will produce more wool. The kind of supplement needed will depend on the actual deficiencies in the range forage. If it is low in phosphorus, a phosphorus supplement is essential. Commonly, such forage is very low in protein, and it may not supply enough total digestible nutrients or net energy to keep the ewes from running down in weight.

In Montana experiments it was generally profitable to feed ewes on winter range 0.3 lb. per head daily of pelleted supplements which supplied not only protein and energy, but also phosphorus and vitamin A.[26] Under their conditions, the results were about as good with low-protein pellets, consisting mostly of grain and molasses, as with high-protein pellets, and the low-protein pellets were cheaper.

In Utah trials with ewes wintered on a saltbush range, the chief need in the supplement was for protein and for phosphorus.[27] Feeding 0.2 lb. per head daily of a 40 per cent protein supplement, either all winter or only the last half, was superior in a South Dakota trial to feeding 0.2 lb. of a 20 per cent protein supplement all winter.[28]

1310. Lambing time.—Proper attention to the flock at lambing time is essential, for heavy losses of lambs often occur when care is lacking. The shepherd should therefore be close at hand to give assistance to any ewes or lambs that need it. In order to know when the ewes are due to lamb, in farm flocks it is wise to keep a breeding record, showing when each was bred. Just before lambing, little grain or other concentrates should be fed, so as to reduce the danger of milk fever. Any tags of long and loose wool about the rear and udder of each ewe should be removed at this time.

It is best to put each ewe in a "claiming" or "lambing" pen immediately after lambing or shortly before. This should be kept bedded with clean straw. The ewe should remain here for 3 or 4 days after lambing, until the mother and her offspring become thoroughly accustomed to each other and the lambs are strong enough to look out for themselves among the flock. The lambing pens may be made by setting up panels 4 feet long, hinged in pairs, along a warm side of the stable. In very cold weather burlap sacks hung on the panels will help keep new-born lambs warm.

Simple triangular lamb brooders, set in a corner of the lambing pen and heated with a heat lamp, will prevent the new-born lambs from becoming chilled in very cold weather.[29]

During lambing the ewe should not be disturbed unless assistance is needed. When the ewes have been fed and managed properly during pregnancy, most of them will lamb with little or no help. Weak lambs sometimes need special attention to save them. A lamb that seems almost lifeless at birth may often be restored by quick attention. Any mucus should be cleaned from the nostrils and mouth. To start breathing, the lamb should be slapped on both sides of the body just back of the shoulders or rubbed briskly with a handful of straw or a burlap bag. Occasionally, it may be necessary to warm a chilled lamb.

If a lamb is unable to nurse within a half-hour after birth, it should have patient assistance. Soon after birth, the stump of the navel cord should be immersed in tincture of iodine to prevent infection with navel ill or other disease.

A ewe that refuses her lamb will usually accept it if they are kept together in a lambing pen, and the lamb helped to suckle a few times. A stubborn ewe may be tied so that she cannot prevent the lamb nursing. In case a ewe loses her lamb, she may often be induced to adopt one of a pair of twin lambs by first sprinkling some of her own milk over it. Still more effective is tying the skin from the dead lamb upon the back of the one to be adopted.

1311. The percentage of increase; weights of lambs at birth.—The number of lambs raised per 100 ewes of breeding age, or the percentage of increase, will vary widely depending on the conditions under which the sheep are kept and also depending on the breed. Fine-wool sheep are less prolific than the mut-

ton breeds, and the percentage of increase can be much greater with farm flocks than under range conditions.

In the western range states, the average number of lambs raised to market age for each 100 breeding ewes varies from less than 60 to 80 or over.[30] In certain fine-wool flocks in Ohio, an average of 80 to 82 lambs were raised per 100 bred ewes.[31]

With ewes of the mutton breeds, kept under excellent conditions, the percentage of increase can be much greater than this. For example, during 24 years at the Wisconsin Station the average number of live lambs born per 100 ewes of various mutton breeds was 161.[32] Such a high percentage of increase can be secured only when the ewes are kept under excellent conditions. Also, to develop a flock that will have a high percentage of increase, ewes must be bred and selected for ability to produce twin lambs.

The percentage of increase of ewes tends to grow greater until they reach the fifth or sixth year. This is doubtless due somewhat to discarding the poorer breeders as 3-year-olds. The larger ewes of a given breed tend to have a greater percentage of increase and their lambs tend to be larger.

Lambs that are large for the breed at birth are usually stronger than small lambs, the death loss is less, and the lambs tend to weigh more at weaning time.[33]

In Wisconsin studies the average birth weights of single lambs were as follows for the various breeds: Shropshire, 9.5 lbs.; Southdown, 9.2 lbs.; Hampshire, 10.6 lbs.; Cheviot, 9.5 lbs.; Dorset, 10.2 lbs.; and Oxford, 10.4 lbs. The average birth weights of the twin lambs were: Shropshire, 7.7 lbs.; Southdown, 7.7 lbs.; Hampshire, 8.2 lbs.; Cheviot, 7.7 lbs.; Dorset, 8.5 lbs.; and Oxford, 8.2 lbs.[32] The triplet lambs were somewhat smaller than the twins. In California studies the average birth weight of Rambouillets was 9.9 lbs.; of Hampshires, 9.3 lbs.; of Shropshires, 8.6 lbs.; of Southdowns, 8.7 lbs.; and of Romneys, 9.0 lbs.[34] In the Wisconsin studies the ram lambs averaged 0.5 lb. heavier at birth than the ewe lambs.

1312. After lambing.—Soon after lambing, the ewe should be given water with the chill removed, but should not be allowed to drink too much at a time. To avoid udder trouble, only a little grain should be fed for the first 2 or 3 days, although the ewe may have all the dry roughage she wishes. Close attention must be given for a few days to see that the lamb is taking milk from both sides of the udder. All surplus milk should be drawn, or better, a needy lamb helped to an extra meal.

As soon as the lambs are able to take more milk, the ewes should be fed liberally enough to insure a good milk flow, for lambs make the most economical gains when they are suckling. The ration should be fairly rich in protein, for the ewes are not only producing milk but are also growing wool, which is composed chiefly of protein.

If there is not enough roughage of high quality for the entire winter, some of it should be saved for feeding after lambing. If possible, plenty of legume hay should be fed, and also silage or other succulent feed. If there is little or no legume hay, it will be necessary to include in the grain mixture more of such feeds as linseed meal, soybean oil meal, or wheat bran.

Several concentrate or grain mixtures are recommended in Appendix Table VII that are suitable for ewes nursing lambs. With good roughage, 1 lb. or slightly more of grain mixture per head daily should be sufficient for the ewes at this time. As soon as good pasture is available for the ewes, they no longer need grain, hay, or other harvested roughage.

All the lambs should be docked when 1 to 2 weeks old. The ram lambs not intended for breeding should also be castrated at this time, except perhaps when the lambs are to be marketed at not over 4 to 5 months of age on a market that does not discriminate against ram lambs of this age.

Up to this age, ram lambs may make fully as rapid gains as wether lambs, and also there is little difference in the quality of carcass.[35] However, on

the large markets ram lambs often sell at a discount of $1.00 per hundredweight, even when no older than this.

When older than 4 or 5 months, ram lambs yield carcasses of distinctly lower value than wethers, as their carcasses are heavy in the fore quarters and contain a smaller proportion of valuable cuts. In hot-house lamb production, the ram lambs are not commonly castrated.

1313. Milking qualities of ewes.—In building up a profitable flock it is highly important to select ewes on the basis of their milk production and nursing qualities, as well as on type and conformation. The rate of gain made by a lamb during the suckling period depends more largely on the amount of milk the dam produces than on any other factor.

In recent Arkansas studies the total milk produced by Hampshire ewes in 12 weeks ranged from an average of 95 lbs. for the lowest yielders to 217 lbs. for the best producers.[36] The daily milk yield was highest the first 4 weeks, declined rapidly the next 4 weeks, and then fell more slowly.

For each additional pound of milk yielded by the high producers, the average daily gains of their lambs were 0.16 lb. more a day than of the lambs of the poor milkers. The lambs getting the most milk gained 59 per cent more from birth to 12 weeks than the lambs of the low milk producers. In a New Hampshire study there was even a larger difference.[37]

Ewe's milk is usually much richer in fat and protein than is cow's milk, having an average of 6.9 per cent fat and 6.5 per cent protein. In studies at the Idaho, New Hampshire, and Wisconsin Stations, the daily yield of milk by ewes of various breeds ranged from less than 2 lbs. to 7.5 lbs., and the fat content from 3.8 to 12.1 per cent.[38] There was a much greater range in fat percentage for the milk of ewes of the same breed than difference between the average composition for the various breeds.

In this country the milk of sheep is seldom used by man, but abroad, especially in certain mountain regions of continental Europe, it is extensively employed, both for direct consumption and for the manufacture of cheese. European milk sheep may yield 3 to 4 quarts of milk daily for 2 months after weaning their lambs.

1314. Pregnancy disease.—Pregnancy disease, also known as ketosis or lambing paralysis, is one of the most common causes of death of pregnant ewes in late winter and early spring, within a month of lambing.[39] It is somewhat similar to ketosis in cows, except that it affects a ewe before parturition, instead of afterward. (**1087**)

Pregnancy disease usually occurs only in ewes that are underfed during pregnancy, especially during the last month or two. The cause seems to be an insufficient supply of readily available carbohydrates, such as starch, to meet the need for energy in the rapid development of the unborn young. As a result there is a greater metabolism of fat in the body and an accumulation of certain normal products of fat metabolism, called ketone bodies, which are toxic when present in excess.

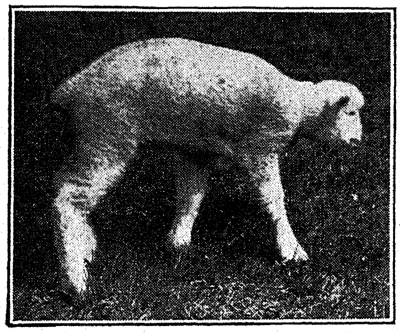
The disease is most common when ewes are fed poor roughage and no grain before lambing. Fortunately, there is generally little trouble from pregnancy disease when ewes are well fed before lambing, as advised in this chapter. It is more apt to occur in ewes bearing twins or triplets than in ewes bearing a single lamb, and it is more frequent in mature ewes than in two-year-olds. Close confinement, lack of exercise, or undue exposure to snowstorms or cold weather may tend to produce the disease. It practically never occurs when ewes are on pasture.

A ewe affected with the disease at first appears sluggish or sleepy. She is reluctant to rise and walks with an unsteady gait. Later, she becomes paralyzed and often lies with the head bent far backward. In an early stage of the disease, the ewe may be saved by hypodermic injections of a glucose solution by a veterinarian, followed by careful drenching with a solution of glucose, cane sugar, or molasses twice a day or oftener. Where the trouble has appeared in a flock, it may help to add molasses to the concentrate mixture fed all pregnant ewes.

Sufficient data are not yet available to prove whether the trouble can be prevented or cured by adding sodium propionate to the ration. As has been shown in Chapter XXVI, this is generally effective in ketosis of dairy cows. (**1087**) In a Maryland test, though

cortisone injection usually cures ketosis in cows, it did not seem to cure pregnancy disease in ewes.[40]

1315. Stiff-lamb disease.—Stiff-lamb disease, or white-muscle disease, is a strange disease of young suckling lambs, which usually becomes apparent when the lambs are 1 to 5 weeks old. The lambs that are affected become characteristically stiff. Some stiff lambs stagger around for several days and then gradually improve, but many become



A STIFF LAMB

Note characteristic gait. (From J. P. Willman, Cornell University.)

so stiff that they are unable to walk or to nurse without assistance. Death is probably not due to the disease itself, but, owing to starvation, the lambs become so thin and weak that they die or are killed by the owner. The disease is not common in most regions, and seems to occur more often in the northeastern states than in other districts.

Post-mortem examinations of stiff lambs shows that certain of the muscles have undergone degeneration, becoming whitish in color. Almost invariably, the disease affects the same muscles on the two sides of the body. The trouble is apparently due entirely to feed and not to any infection.

In experiments during 13 years at the New York (Cornell) Station, stiff lambs were produced experimentally each year when ewes were wintered on a ration of cull beans, oats, barley, and alfalfa hay of good quality.[41] The disease still occurred when the ewes had abundant exercise and when they were fed so that they did not become unduly fat.

In contrast to the results on this ration, not a single stiff lamb was produced by ewes which were fed a ration of wheat bran, oats, corn silage, and mixed clover-and-timothy hay. Farmers who had previously suffered severe losses from the disease reported much better results after changing to this ration or one which was similar.

The trouble was greatly lessened when considerable wheat bran was added to a ration that otherwise produced the disease, and it was prevented by the feeding of wheat germ meal to the ewes and lambs. Since wheat germ meal and wheat bran are rich in vitamin E, the effect of this vitamin was then tested. It was found that the disease can be prevented or cured by feeding rations containing liberal amounts of vitamin E or alpha-tocopherol (223).

Where there has been trouble from the disease, it is recommended that one-quarter to one-half pound per head daily of wheat germ meal be included in the concentrate mixture fed the ewes a few weeks before lambing, or that 50 per cent by weight of wheat bran be used in the mixture. In addition, the lambs should be fed wheat germ meal or wheat bran in a creep. Concentrated forms of vitamin E have also been found effective in preventing or curing the disease.

In some field trials vitamin E supplements have prevented the occurrence of stiff lambs, but not in certain others.[42] Other causes than a lack of the vitamin may therefore be connected with the trouble.

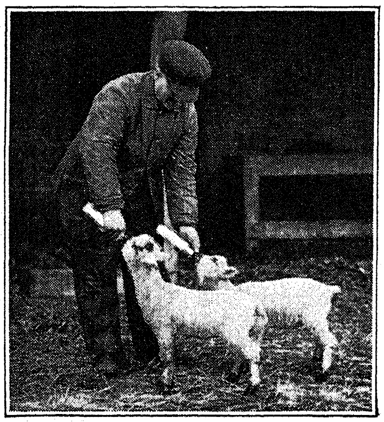
An entirely different type of stiffness in lambs is produced by a disease called arthritis.

1316. Orphan lambs.—If possible, a foster mother should be found for any orphan lamb. However, in case this cannot be done, the orphan can be successfully raised on cow's milk, though close attention is necessary the first month.[43] For the first 3 or 4 days the lamb should have some colostrum ewe's milk, if possible, by letting it nurse ewes whose lambs are not yet old enough to take all their milk.

The cow's milk should be whole, fresh, and warmed to approximately 100° F. It should be fed in a bottle with a suitable nipple that is carefully washed after each feeding. For the first day or two after birth, the lamb should be fed every 3 to 6 hours, only 2 to 4 tablespoonfuls being given at a time. After the lamb is 2 to 3 weeks old, it is not necessary to feed it more than 3 or 4 times a day. The lamb should be given other feed in addition to milk when it is about 2 weeks old. A suitable mixture is the one suggested in the following article for creep-feeding. (1317)

In some studies lambs that have received some colostrum have been raised successfully on a "synthetic milk," or milk replacer.[44] (1142)

1317. Raising the lambs.—During the suckling period of 4 to 5 months, well-fed lambs will make about two-thirds of the growth and the gain in weight that they will make during the entire first year.[45] Furthermore, the most economical gains are made at this time. It is thus very important that lambs be well fed during this period.



ORPHAN LAMBS

Care and patience are necessary to raise orphan lambs on a bottle.

Until pasture is ready in the spring, early lambs should be fed both grain and hay in a "creep," beginning when they are about 2 weeks old. Indiana experiments show that lambs fed grain in a creep at this time make larger and cheaper gains, reach a better finish, and return a greater profit than those not thus fed.[46] It may not pay to creep-feed lambs that are born less than a month before they go to pasture, as they will not learn to eat much feed by that time.

The creep is made by fencing off a corner of the barn with panels in which there are openings just wide enough so the lambs can pass through, while the ewes are kept back. Within the creep there should be a hay rack and a low, shallow grain trough with a board lengthwise above the trough to prevent the lambs from jumping into it. In this trough a suitable concentrate mixture is fed, only a little being sprinkled at first. Legume hay of choice quality should also be supplied. Fresh feed should be put in once or twice a day, and the refuse can be fed to the ewes.

An excellent mixture for creep-feeding lambs is corn, 20 or 30 lbs.; oats, 20 or 30 lbs.; wheat bran, 10 lbs.; and linseed meal or soybean oil meal, 10 lbs. After the lambs are 5 to 6 weeks old, there is no advantage in grinding most grains for them. (1286)

If the lambs are all to be fattened for market, grain alone may be used for creep-feeding, because the milk will furnish ample protein. A mixture of half corn and half oats is often used. In Indiana and Kentucky tests cracked corn produced as rapid or nearly as rapid gains, and also cheaper gains, than such a mixture as corn, oats, and linseed meal, or as more complex mixtures.[47]

Good pasture should be provided for ewes and lambs as early in the spring as possible. The change to pasture should be gradual, the flock being turned on pasture for only 2 to 4 hours at first. Letting them fill up on hay before being turned out to pasture the first time, helps prevent digestive disturbances. If there has been any trouble from the stiff-lamb disease, it is best to turn the lambs out only about 15 minutes at first. Shade and fresh water should always be provided ewes and lambs on pasture.

Ewes on good pasture need no grain or other harvested feeds. Also, with the possible exception of early lambs to be marketed as spring lambs at weaning, it does not generally pay to creep-feed lambs running with their dams on first-rate pasture.[48] On the other hand, if there is a shortage of pasture forage, the lambs should be supplied with grain or a suitable mixture in a creep.

Corn or a mixture of corn and oats is very satisfactory for creep-feeding to suckling lambs on pasture. In Kentucky trials cracked corn produced larger and more economical gains than a mixture of corn, oats, and linseed meal or a mixture of corn and a special commercial milk substitute.[49] Many sheepmen, however, prefer such a mixture as the one suggested previously.

During the summer a lamb on pas-

ture will consume nearly as much feed as a dry ewe, according to Nevada trials, and a ewe and her lamb will consume twice as much feed as a dry ewe.[50]

1318. Marketing lambs early; feeding after weaning.—Where farm lambs are raised under good conditions and with plenty of pasture, a large proportion of them should be fat enough for marketing when they reach weaning age. Especially in the case of early lambs, it is often most profitable to sell such lambs at this time.[51] Lambs thus marketed early, before the western range lambs reach the market, usually bring a considerably higher price per 100 lbs. than if marketed in late fall or in winter.

Lambs that are to be retained in the flock and those which are not sufficiently fat for market should be weaned at 4 to 5 months of age. This should be done for their own good as well as to allow their dams a rest before another breeding period. If possible, advantage should be taken of a cool spell in summer to wean the lambs, as they will then be more comfortable during this trying period.

The lambs should be so far separated from their dams that neither can hear the bleating of the other. For a few days the ewes should be held on short pasture or kept on dry feed in the yard, so as to reduce their milk flow. The udders must be examined, and, if necessary, as is often the case with the best mothers, they should be milked out a few times, so inflammation will not result.

It is especially important to provide fresh pasture, free from parasites, for the lambs after weaning. Profitable gains cannot be expected if the lambs are taken from their mothers and left on a pasture infested with parasites and where the feed is scanty.

Whether or not to feed grain to lambs after weaning will depend on the relative prices of grain and pasture and on the premium paid for well-fattened lambs. Ohio experiments have shown that if really good pasture is provided, the feeding of grain to lambs after weaning is not necessary for the economical production of well-finished lambs.[52] If first class pasture is not available for the lambs after weaning, it may be best to take them off pasture and fatten them in dry lot on a suitable ration.[53]

Ewe lambs to be retained in the flock need no grain when grazing is good. Ram lambs require grain during the fall to secure proper development, whether they are to be sold as lambs or retained until yearlings.

Ewe lambs being raised as flock replacements can be wintered satisfactorily on only legume or mixed hay, with other good roughage as available, if the supply is abundant and if they are well fed the second winter previous to lambing.[54] With poorer roughage, they should receive enough supplemental concentrates the first winter to keep them growing thriftily.

Under range conditions it is important to supplement winter range when necessary for proper growth of the ewe lambs.[55]

1319. Spring lambs.—Early lambs marketed from April to July 1 or early July are called "spring lambs" on the market. Raising spring lambs is of much importance in the southern and southwestern states and also in certain valleys of the West.[56] In the warmer districts the ewes can be maintained chiefly on pasture throughout the year, greatly reducing the cost of feed. Also, no expensive shelter is required.

Unless the ewes and lambs have excellent pasture, the lambs should be fed grain or a suitable concentrate mixture in a creep, so they will be ready for market when prices are best. The lambs should be well finished at 3 to 5 months of age, weighing 55 to 70 lbs.

Some farmers, especially in certain western districts, follow the plan of buying in the fall ewes which have been discarded from range flocks on account of age or poor teeth, and breeding them for the production of one crop of spring lambs. Such ewes must be fed good rations, including plenty of grain both before and after lambing, so they will be fat enough to sell well when their lambs are marketed, or a little later.

1320. Hot-house or winter lambs.—In certain sections of the eastern states there is a profitable market for "hot-house" or winter lambs. The term "hot-house" lambs does not mean that they are raised in artificially warmed quarters, but is used because they are produced at an unusual season and are therefore comparable to the out-of-season products of hot-houses. The market for hot-house lambs is confined mostly to the large eastern cities, where they are consumed chiefly in high-class hotels, restaurants, and clubs. This specialty in sheep production should be undertaken only by experts who have nearby markets that will pay the high prices such products must command.[57]

The demand for hot-house lambs comes from December, or even earlier, up to Easter, the prices usually being best early in this season. Hot-house lambs must be fat, for the condition of the carcass is more important than its size. Lambs that are not well finished or that have poor conformation bring unsatisfactory prices. The lambs must therefore be forced ahead rapidly by feeding them a suitable concentrate mixture in a creep. Thus fed, they should be fat at 40 to 60 lbs. live weight. The lambs are dressed on the farm, according to the demands of the market to which they are to be shipped.

For the production of hot-house lambs, the ewes must be bred in the spring, instead of at the usual season in the fall. The ewes best suited for this purpose are purebreds, grades, or crossbreds of the Dorset, Merino, or Rambouillet breeds, for the other breeds will not usually breed at the right season. Crossbred Dorset-Merino ewes are excellent, when bred to a good mutton ram.

The ewes should have abundant pasture during the summer and fall, so they will be in condition to provide a good milk flow. After lambing, the ewes should be fed liberally on a good concentrate mixture and legume hay, with silage in addition, if available. As has been pointed out, the lambs should receive additional feed in a creep, so they will be ready for market as soon as possible.

1321. Cost of keeping ewes; net returns.—The cost of maintaining ewes will vary widely in different parts of the country. The expense will be reduced considerably when the flock can get an important part of the fall and winter feed by grazing on stalk and stubble fields, thus utilizing feed that might otherwise be wasted.

Where no such grazing is available, it will require 400 to 600 lbs. or more of hay or other dry roughages (after deducting the amount wasted) to carry a breeding ewe of average size, weighing 100 to 150 lbs., through the winter period of 5 to 6 months. Also, for the best results about 20 lbs. of concentrates per ewe should be fed prior to lambing and perhaps additional concentrates for flushing the ewes at the breeding season. In the case of ewes lambing early, additional concentrates will be needed for the ewes and lambs before the pasture season.

In addition to the cost of winter feed and of pasture, in estimating the total cost of keeping ewes there must be included the man and the truck or horse labor, the interest, depreciation, and mortality risk on the ewes, the housing charge, and any miscellaneous expenses. On the credit side are the wool and lambs produced and the value of the manure.

The excellent net returns that can be secured from a well-fed and properly managed flock of ewes are shown by the record of a flock of 42 to 88 western ewes over a period of 7 years, 1946 to 1952, at the Spooner Branch Station in Wisconsin.[58] This station is located on very sandy land, but has been brought to good fertility by fertilization and careful management. The ewes were bred to purebred mutton rams.

Over the 7 years, the average percentage of lambs raised was 151 per cent, and the average weight of fleeces from the ewes was 9.7 lbs. The average net labor return per ewe was $22.89, after deducting all expenses for feed, veterinary services and medicine, shear-

ing, ram cost, death losses, and marketing wool and lambs.

In a 10-year study on farms in southeastern Minnesota, it was found that average amounts of feed consumed annually per head of mature sheep, in addition to pasture, were 60 lbs. concentrates, 144 lbs. tame hay, 87 lbs. wild hay and corn fodder, and 130 lbs. silage.[59] In these flocks, which contained an average of 36 head of mature sheep equivalent, the percentage lamb crop was 96 per cent; the average wool yield, 7.0 lbs.; and the annual death loss 9 per cent. The total value of lambs and wool was a little more than twice as great as the total feed cost.

The average amounts of feed required yearly per head in 103 flocks in western New York, containing an average of 58 sheep, were 46 lbs. of concentrates, 486 lbs. of hay, and 190 lbs. of other roughage, including silage, fodder, and stover.[60] On the average, 7.8 lbs. of wool were sold per head, 97 lambs were raised per 100 ewes, and 6.1 hours of man labor were required a year per sheep. The cost of feed, including pasture, was 58 per cent of the total gross cost, before allowing a credit for the value of the manure.

In Pennsylvania tests purebred Shropshire ewes averaging 172 lbs. in weight required an average of 2.5 lbs. legume hay, 3.1 lbs. corn silage, and 0.2 lb. concentrates per head daily in winter.[61] An average of 85 lbs. of bedding was needed per ewe during the winter and 735 lbs. of manure were produced per ewe. The ewes sheared an average of 7.66 lbs. and the average weight of the lambs at weaning was 59 lbs. Delaine-Merino ewes required somewhat less feed because of their smaller size and sheared 11.1 lbs. Their lambs averaged 53 lbs. at weaning.

1322. Factors affecting the net income from sheep.—The various cost-accounting studies that have been made of sheep and wool production show clearly that some of the most important factors affecting the net income are the following: (1) A flock of sufficient size to make possible the efficient use of labor, buildings, equipment, and ram. (2) A flock that has been selected to produce a high yield of wool per ewe and a high percentage of lambs as well. (3) Proper feed and care of the ewes, so that they will produce vigorous lambs and furnish plenty of milk for them. (4) Plenty of good pasture, preferably rotated so as to aid in the control of parasites. (5) Thorough control of stomach worms and other internal parasites, and also control of ticks and lice.

1323. Internal parasites.—In all humid regions stomach worms and other internal parasites may seriously reduce the income from sheep unless damage from these parasites is prevented. Severe infection with internal parasites retards growth, prevents fattening, reduces the wool yield, lowers the resistance to other diseases, and may cause heavy death loss. Lambs are usually affected more seriously than older sheep.

The eggs of the stomach worms pass out in the droppings of the sheep and are scattered about the pasture, where they soon hatch and develop to the larval stage. Sheep become infected only by swallowing the worms at this stage.

Fields on which no sheep or goats have grazed for a year, and those that have been plowed and cultivated since they were grazed, are practically free from infestation. Where the winters are cold, the parasites on a pasture will be largely killed during the winter, if there are no sheep on it. Also, keeping sheep off a field for 3 months in summer will greatly reduce the infestation with parasites. During warm weather, clean pastures may become infested in 10 to 20 days of grazing.

To prevent serious trouble from internal parasites, medicinal treatment should be combined with proper feeding and good pasture management. Thrifty, well-fed sheep are much better able to resist parasites than those that are rundown. If the flock could be moved to fresh uncontaminated pasture every 2 to 3 weeks during the grazing season, there would generally be little trouble from internal parasites. However, this is not practicable on most farms. It is therefore

necessary to rely largely on medicinal treatment for parasite control.

The best methods for preventing trouble from internal parasites will depend on the climatic conditions in any region. Specific advice should therefore be secured from a local veterinarian who has had experience with sheep diseases, or from the state agricultural college or county agricultural agent.

The use of phenothiazine is largely displacing the older vermifuges for the control of internal parasites in sheep, because it is effective against more kinds of parasites than any other vermifuge. In some humid regions the following is an effective plan of control: Drench the sheep with phenothiazine in late fall or early winter, after they come to the barn. Drench them again with phenothiazine before they go to pasture in the spring. Ewes should not be drenched within 2 months of lambing. During the grazing season give the sheep access to a mixture of 1 lb. of phenothiazine and 9 lbs. of coarse salt, and provide no other salt.

When this system is combined with good pasture management and with as much rotation of grazing as is practicable, it may provide good control without other treatment. Often, however, it is necessary to drench the sheep at monthly intervals during the grazing season with the combined copper sulfate-nicotine sulfate solution. This eradicates certain worms, especially tapeworms, which are not controlled by phenothiazine. Feed and water should be withheld for 10 to 15 hours before sheep are drenched with this solution, and for 4 to 6 hours afterwards. Withholding feed and water is not necessary when sheep are drenched with phenothiazine.

1324. External parasites.—To eradicate ticks or lice, both mature sheep and lambs should be dipped with a suitable preparation in the spring as soon as the cuts have healed on the sheep that have been shorn. If badly infested, the sheep should be dipped a second time to kill any parasites that were in the egg state before. A second treatment is not needed if a dip is used which leaves an effective residue in the fleece for a sufficiently long time. A second dipping should be 24 to 28 days later for ticks and 14 to 16 days later for lice. The sheep should be dipped on a clear, warm morning, so that they will dry during the day. In fall the flock should be dipped again, if necessary.

Power dusters have recently been developed for applying a suitable insecticide in dust form to eradicate ticks and lice. This method is especially advantageous in cold weather when dipping is injurious.

In case of sheep scab, prompt and thorough dipping with an effective preparation is necessary.

1325. Range sheep production.—The great numbers of sheep in our western states are mostly kept under range conditions.[62] The ranges grazed by sheep are usually the rougher areas of the plains, foothills, and mountains.

The high mountain ranges furnish excellent grazing for sheep during the summer months, for there is usually an abundance of water and good pasturage, and the days are cool. The plains and the semi-desert ranges, which are too hot and dry in summer, furnish winter range, and during the spring and fall the foothills are used to good advantage. Sheep do well on sagebrush and salt-sage browse, neither of which is palatable to cattle, and cattle can browse on the higher growing species which sheep cannot reach. For grazing throughout the year, 4 to 20 acres of range are commonly needed for a mature sheep.

The unit, or band, of range sheep may vary considerably in size, but it usually contains 2,000 to 2,500 sheep. From lambing time to weaning, 1,000 to 1,500 ewes and their lambs are usually kept in one band, and after the lambs are weaned, two bands of ewes may be combined for the breeding and winter period. During lambing, a smaller number of ewes is run together.

Most of the western sheep producers use the same general method in handling their sheep. A band is put in charge of one herder, who, with his dogs, stays with the sheep, day and night,

throughout the season. The herder is quartered in a covered wagon, equipped for his needs, except when he is near headquarters or in summer when the sheep are on a high mountain range where the wagon cannot follow. A tent is then used for shelter.

A camp tender, with a wagon or pack animals, supplies the herder with food and moves his camp, as the sheep need new grazing ground. One camp tender may take care of two or more herders, and in large enterprises a range foreman is usually in charge of several bands. Additional help is needed during lambing and shearing. In Texas, a common method is to keep the range sheep in fenced pastures, where they can graze undisturbed. Under this system one man can care for a larger number of sheep, and the sheep can make better utilization of the feed than on an unfenced range.

On the ranges the sheep receive no feed except the pasturage during the growing season, and often a range at low altitude furnishes most of the winter feed, especially in the southern districts. Usually, however, it is necessary to make provision for additional feed during winter, such as alfalfa and other hay, or cottonseed cake or meal. The feeding of supplements to ewes wintered on the range has been discussed previously in this chapter. (**1309**)

Where early lambs are produced, as in certain valleys of California, Oregon, and Arizona, the ewes lamb in sheds from late January to early March. The lambs are raised on the valley and foothill ranges and are marketed as fat "spring lambs" in spring or early in summer, before the low-lying ranges dry up. In this system aged ewes are frequently used, which would not thrive under the usual range system.

The more general range practice is to have the ewes drop their lambs on the range, usually in May. After the ewes are sheared, the bands are gradually moved to the high mountain ranges where they graze during the summer. The wether lambs and also the ewe lambs which are not needed for replacements in the ewe flocks are marketed in the fall, generally in September and October. A large proportion of the lambs may be fat enough for immediate slaughter, if the summer forage has been abundant. The rest are fattened for market by men who make this a speciality.

II. Fattening Lambs and Sheep

1326. Fattening feeder lambs.—Considerable numbers of the lambs raised on the western ranges are not fat enough for slaughter at the time they are marketed. They are therefore sold as feeders and then fattened in districts where grain and other concentrates are cheaper than in the range area. Also, many farm-raised lambs are not fat enough for sale at the end of the pasture season. These are fattened during late fall and winter.

The juiciness and flavor of lamb meat are greatly improved by proper fattening. Texas experiments indicate, however, that the tenderness of lamb is not increased by fattening.[63]

At one time most of the western lambs were fattened by large operators who each fed thousands of lambs a year. Now, most of the lambs are fattened by farmers, who finish one or more carloads. They raise most of their own feed and usually consider that enough fertility is returned to their land through the feed lot to pay the labor cost of feeding.

Just as is the case in fattening feeder steers, good judgment in purchasing the feeder animals and in selling them at the right time are exceedingly important in determining whether there will be a profit or a loss in the feeding operations. The cost of the feeder lambs forms more than half the cost of the fattened animals. Also, the cost per 100 lbs. of the gains made in the feed lot is usually greater than the selling price per 100 lbs. of the lambs when fat. Therefore, to make a profit the fat lambs must sell at a higher price per hundredweight than their cost as feeders. In other words, a margin is required between the initial cost and the selling price. (**1188**)

Sometimes lambs are fattened under

a "contract" system. The farmer-feeder does not buy the lambs, but furnishes the feeds and fattens the lambs under a definite contract with the producer. Often a specified price per pound is paid for the gains made.

In fattening lambs it must be borne in mind at all times that the object is to convert a thin animal into a finished product—a lamb fat enough to meet the market demands. Each year many farmers lose money because they dump half-fattened lambs on the market, where they again are sold as feeders, to be finished for the market by someone else, who is better acquainted with the market demands.

Usually men who feed lambs only occasionally make less of a financial success of the undertaking than those who feed each year. The latter may lose money in the unprofitable years, but this will be offset by good returns the rest of the time. Just as important, they gain experience in this business, where good judgment is of great value.

1327. Types of lamb fattening.—Large numbers of lambs are fattened in the vicinity of the western beet-sugar factories, where the beet by-products—beet pulp, beet tops, and molasses—are fed, along with alfalfa hay and usually some grain in addition. In these districts and in general west of the Missouri River, most of the lambs are fed in open yards, with no shelter except a wind break. (1289)

The hay is usually fed in lanes which extend between 2 rows of feed lots, each of which accommodates 400 to 500 lambs. The low fences bordering the lanes have a 7- or 8-inch space between the first and second boards, through which the lambs feed on the hay. The hay from stacks is hauled down the lanes and piled along the fences, being pushed up to them 2 or 3 times a day as it is eaten away. Sometimes racks are used for the hay, or chopped hay is fed in self-feeders. The grain is fed in flat-bottomed troughs.

In the corn belt many farmers fatten western lambs in late fall and winter on harvested feeds, sheltering them in a barn or an open shed, with or without an exercise lot. Usually, all or nearly all the feed is raised on the farm, with the exception of protein supplements. Fattening lambs chiefly on pasture in the fall, and fattening them in corn fields are other methods used. (**1336, 700**) Often lambs are grazed on stubble fields or on aftermath in meadows and then finished in a dry lot. In the southern plains states, lambs are often fattened chiefly by grazing them on fields of winter wheat. Many lambs are also fattened largely on pea-vine silage in the vicinities of pea canneries, especially in Wisconsin.

In Michigan and eastward, the lambs are generally not turned out from the barn or shed for exercise. Commonly, the lambs are brought to full feed as quickly as possible and then are given all the grain they will clean up. Often they are self-fed, as is discussed later. (1335)

Several large feeding yards are located near some of the large markets, on the main railroads from the West. Here, lambs which have been fattened in the western states are often fed and rested for a few days, so they will reach the market in good condition and without heavy shrinkage. Also, lambs may be carried through the entire fattening period at such yards.

Some men usually fatten two lots of lambs each season, marketing the first in early winter and the second late in the spring. Should the weather grow warm before the lambs are finished, they are often shorn so they will make better gains. (**1293**)

Others, who market their lambs in the spring, when prices are usually higher than in the winter, use a deferred system of fattening. They buy small lambs in the fall, when it is easier to get thrifty feeders than it is in winter. Then they feed them on only hay or other roughage until 60 to 80 days before the time they are to be marketed, when grain feeding is started and the lambs are finished on a liberal feed of grain. During the preliminary period on roughage alone, the lambs make very little gain, but the total cost of fattening will

usually be less than if a half allowance of grain is fed during the entire time.[64]

This method utilizes a large proportion of roughage and requires a minimum amount of concentrates.[65] Unless grain is high in price in comparison with roughage, the cost of the gains is apt to be greater in the deferred system of fattening than when grain is fed from the beginning of the fattening period.

1328. Selecting feeder lambs.—The most desirable feeder lambs are thrifty, broad, compact, and relatively low-set, and have smooth skin free from wrinkles when fattened. Such lambs yield the best carcasses and thus bring the highest price per hundredweight. Feeder lambs of this type naturally cost more per 100 lbs. than those of lower grades, and therefore do not always yield the greatest net return from fattening.

Thrifty lambs that lack some of the desirable qualities may make nearly as rapid and economical gains as do feeder lambs of the best grade, but generally sell at a lower price when fattened. Good judgment is consequently needed in deciding what grade or type of lambs to purchase.

Most of the feeder lambs from the northern range states weigh 75 to 85 lbs. when loaded in the West. On receipt at eastern feed lots, the lambs usually weigh 65 to 75 lbs. The lambs from the southwestern ranges are usually somewhat lighter.

During a fattening period of 80 to 120 days lambs should gain 25 to 30 lbs. per head, which brings them to the size desired by the market. The demand is generally best for well-fattened lambs weighing 95 to 100 lbs., and fat lambs heavier than 105 to 110 lbs. often sell at a discount.

Light-weight lambs commonly require a longer fattening period than do heavier lambs to reach the same degree of fatness, but there may be little difference in the amounts of feed required per 100 lbs. gain.[66]

Some men specialize in fattening light-weight lambs, or "peewees," sorted out from the shipments of feeder lambs from the ranges. These can usually be bought at a considerably lower price than the larger ones. Though some of these "peewees" are apt to be unthrifty, most of them are merely younger than the rest or are small because their mothers were poor milkers.

If they are thrifty, such lambs, usually weighing 50 lbs. or less, will make nearly as rapid gains as larger ones and their gains will generally be cheaper, because of their younger age.[67] Naturally, such lambs require a longer feeding period to reach a certain market weight or degree of fatness, and good shelter and more care are necessary in feeding them. Also, they should be fed apart from larger and stronger lambs.

Feeder lambs produced in the humid districts are more apt to be infected with stomach worms and other parasites than are western feeder lambs, especially those from the northern ranges, and therefore often make less rapid and more expensive gains. However, if the lambs are thrifty and are thoroughly drenched before being placed on feed, they may make as good gains as western lambs.[68] The purchase and fattening of cull native lambs should be undertaken only by an expert, as the undertaking may be hazardous because of heavy death losses.

There is not enough difference in the gains made by ewe lambs and by wether lambs in the feed lot, or in the market value when fat, to cause any decided preference among experienced men. However, wether lambs usually make slightly more rapid gains than do ewe lambs.[69]

Fine-wool lambs are apt to make less rapid and less economical gains than do lambs having considerable mutton blood. Smooth-bodied Rambouillet lambs generally make larger gains than wrinkly, fine boned lambs of fine-wool breeding, and yield much better carcasses.[70]

1329. Gains made by fattening lambs; feed per 100 lbs. gain.—The amounts of feed consumed per head daily by fattening lambs and the feed requirements per 100 lbs. gain are shown by the following summary, compiled by the author, of the results of many experi-

ments in which a ration of corn grain and alfalfa or clover hay has been fed. This ration is excellent and may be taken as a standard with which other rations are compared.

There are given first in the table the average results from experiments in which 44 lots, including a total of 1,171 lambs, were fed for periods averaging 80 days on a liberal allowance of shelled corn (1.1 lbs. a head daily or more, on the average) with alfalfa or clover hay for roughage. The results are also presented for 43 experiments in which a total of 2,300 lambs were fed for an average of 97 days on a limited allowance of shelled corn (an average of less than 1.1 lbs. a head daily) and all the alfalfa or clover hay they would eat.

and their weights in the feed lot at the end of the experiment. Under commercial conditions, the amount of gain is usually considered to be the difference between the initial purchase weight, before shrinkage in shipment to the farm, and the final shrunk weight at the market.

1330. Results in commercial lamb fattening.—The results secured by farmers in the commercial fattening of lambs are shown by studies during 5 years, 1931–35, on Michigan farms where a total of about 130,500 lambs, chiefly western, were fattened.[71] On the average, 796 lambs were fattened each year per farm. The lambs averaged 63 lbs. in weight at the start and were fed for an average of 110 days. During this period,

Fattening lambs on an excellent ration

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Feed for 100 lbs. gain Hay Lbs.
Corn allowance liberal				
Shelled corn, 1.3 lbs. Alfalfa or clover hay, 1.4 lbs.	63	0.34	387	418
Corn allowance limited				
Shelled corn, 0.9 lb. Alfalfa or clover hay, 2.3 lbs.	62	0.31	305	727

The lambs fed the liberal allowance of corn ate 1.3 lbs. corn and 1.4 lbs. alfalfa hay and gained 0.34 lb. per head daily. For each 100 lbs. gain in weight they consumed 387 lbs. corn and 418 lbs. hay. The lambs fed the limited allowance of corn, with all the legume hay they would eat, gained only a little less rapidly (0.31 lb. per head daily), because of the good quality of the hay fed in the experiments. For each 100 lbs. of gain these lambs required 305 lbs. corn and 727 lbs. hay.

It should be borne in mind that in these experiments thrifty lambs were fed on feeds of good quality by experts. Also, the gain reported in feeding experiments differs from that secured in commercial feeding operations. In a feeding experiment the gain is the difference between the initial weights of the lambs in the feed lot when the experiment is started

the average gain per lamb, or the difference between the purchase weight at the market and the sale weight at the market plus the weight of wool shorn from some of the lambs, was 26 lbs., or 0.24 lb. per head daily. In similar Colorado studies of lamb-feeding results over a 22-year period, the average daily gain was 0.19 lb. for an average feeding period of 145 days.[72]

On the Michigan farms 620 lbs. of grain and other concentrates and 550 lbs. of hay and other roughage were required per 100 lbs. of net gain in weight, based on market weights and deducting the initial weights of the lambs that died. The lambs were fed an average of 1.3 lbs. grain and other concentrates and 1.1 lbs. hay and other roughage per head daily. The total average amounts of feed used per finished lamb were: corn, 62 lbs.; oats, 14 lbs.; grain screenings and

salvage grains, 35 lbs.; other concentrates, 30 lbs.; hay, 88 lbs.; and other roughage, 37 lbs.

The cost of feed and labor amounted to 95 per cent of the net on-the-farm expenses, after credit was allowed for the value of the manure.

1331. Rations for fattening lambs.—To secure rapid and economical gains, lambs must be fed a well-balanced ration with a liberal amount of grain or other concentrates, and also plenty of good roughage. Many different rations are satisfactory. Several example rations, which are adapted to conditions in various regions, are given in Appendix Table VII.

As has already been emphasized, a ration of corn or other grain and plenty of good alfalfa or other legume hay is excellent for fattening lambs. (1329) Information is given in Chapters XX and XXI concerning the relative values of the different grains for lamb feeding, and in Chapter XVI concerning the values of the various kinds of legume hay. Other carbohydrate-rich feeds, such as dried beet pulp, wet beet pulp, cane or beet molasses, and hominy feed, can be used to replace all or part of the grain for fattening lambs. These and other feeds are discussed in the respective chapters of Part II.

It has been shown in the preceding chapter that if an abundance of good legume hay is fed with corn grain, it is doubtful if it will ordinarily pay to add a protein supplement to the ration. (1270) When barley, oats, or wheat is fed instead of corn, there is still less benefit from adding a protein supplement.

Corn silage or sorghum silage is excellent as part of the roughage for fattening lambs and has a high value per ton when thus fed. Because such silage is much lower than legume hay in protein, it usually pays well to add a protein supplement to a ration of grain, such silage, and legume hay. (1271)

Corn silage or sorghum silage can even be used as the only roughage for fattening lambs, if care is taken to feed the proper amount of protein supplement and also of ground limestone or some other calcium supplement. (1278) The gains are generally more rapid, however, when hay is fed in addition to silage. Also, the silage has a higher value per ton when thus used than when it is fed as the only roughage.

In 3 New York experiments lambs fattened on a ration of shelled corn, protein supplement, alfalfa hay, and corn silage gained 0.40 lb. per head daily.[73] Others fed corn silage as the only roughage with shelled corn, protein supplement, and ground limestone, gained 0.36 lb. daily. In these experiments corn silage was worth 56 per cent as much per ton as alfalfa hay when fed in combination with hay, but only 37 per cent as much as alfalfa hay when used as the only roughage.

STOVER NOT A GOOD ROUGHAGE

Corn stover is too low in nutrients to be a satisfactory roughage for fattening lambs.

When lambs are fed both corn or sorghum silage and legume hay, they are generally allowed to eat as much of each as they will clean up satisfactorily. However, the advantage from feeding legume hay in addition to the silage can be gained when only a small amount of legume hay is fed.

In New York experiments lambs made slightly more rapid gains when fed only one-quarter pound of alfalfa hay, with silage and corn grain full-fed and with sufficient protein supplement to balance the ration, than did others fed more hay.[74] Of course, more protein sup-

plement was needed to balance the ration that had the very small amount of alfalfa hay.

Mixed hay of good quality and containing a considerable proportion of legumes is a satisfactory substitute for legume hay in feeding fattening lambs. For lambs, grass hay should be early cut and well cured. Otherwise, it is much inferior to legume hay. Information is given in the respective chapters of Part II concerning various kinds of grass hay and also other roughages that can be used for fattening lambs, including corn fodder, sorghum fodder, bean pods or bean straw, sugar beet tops, and cottonseed hulls.

1332. Getting the lambs on feed.—Lambs that are not used to grain or silage must be accustomed to these feeds gradually, or scouring and other digestive troubles will result, and perhaps even heavy death losses. When feeder lambs are received on the farm, they should be given only a feed of hay for their first meal, and this should be preferably mixed hay or grass hay, as pure legume hay may be too laxative for this first feed. It is risky to turn onto abundant pasture hungry feeder lambs that have just arrived, as this may cause bloating or scours.

After the lambs have rested from shipment, they may be fed as much hay or other dry roughage as they will clean up, but only a small amount of grain (not over 0.1 to 0.2 lb. per head daily) should be fed at first and only a little silage. The grain should be sprinkled along the trough, so no lamb can get too much. The allowance of grain should be increased gradually, until in 4 to 5 weeks the lambs are receiving 1.0 to 1.25 lbs. of grain per head daily. During this time no more grain should be fed than will be cleaned up in about 15 minutes. If silage is fed, the amount should also be increased gradually, until the lambs are getting all the silage they will eat twice a day.

If it is desired to fatten the lambs as rapidly as possible by feeding them all the grain they will eat, further increases should be made cautiously, and only if all the lambs are cleaning up their feed regularly. Example rations for fattening lambs when on full feed are given in Appendix Table VII.

In no case should the getting of the lambs on feed be hurried, for this is apt to cause serious digestive trouble. It is wise to start the lambs on a mixture consisting chiefly of a bulky feed, like oats or wheat bran. The proportion of corn or other heavy feed is then gradually increased. When the lambs are on full feed, corn is very often fed as the only concentrate, with a small amount of protein supplement, if this is needed to balance the ration. On warm days in winter it is often necessary to reduce the grain allowance slightly, or the lambs may go off feed.

Sheep feeders do not begin operations at an early hour in winter, preferring not to disturb the animals until after daybreak. The lambs are usually fed twice a day, grain being given first, followed by silage, if this is used, with the hay last. Fattening lambs may gain a trifle faster when fed grain more often than twice a day, but it is doubtful whether this is worth the additional labor.[75]

Plenty of salt and fresh water should always be provided. The troughs in which grain is fed should be kept clean, and there should be ample space, so that each lamb can get its share of grain. If any evidence of lice, ticks, or scab is found, the lambs should be dipped thoroughly before they are put on feed. When necessary, they should be drenched to eradicate stomach worms, but this is not usually needed in the case of western range lambs.

Regularity and quiet are of especial importance to secure good results in fattening lambs.

1333. Amounts and proportions of concentrates and roughage.—Experiments have shown clearly that under conditions throughout the corn belt and the eastern states, it is usually most profitable to give fattening lambs a liberal allowance of grain after they have been

brought onto feed, except when it is desired to fatten them slowly for a later market.[76] If lambs are fed about as much grain as they will clean up twice a day, in addition to what good hay or other roughage they will eat, they will make rapid gains at a reasonable cost, reach a good market finish, and sell at a higher price than if less thoroughly fattened.

It is very important to feed fattening lambs plenty of good roughage.[77] Experiments have shown that if the ration, on the air-dry basis, has more than about 50 per cent of corn or other heavy grain, the danger of death losses from overeating disease is increased. Also, even when this does not occur, the feed cost per 100 lbs. gain is apt to be higher, when too large a proportion of grain is fed.

Kansas experiments have shown that lambs utilize the nutrients in their feed more efficiently when there is a proper balance between concentrates and roughage.[78]

If one wishes to fatten heavy lambs as rapidly as possible, so that they get fat before they get too heavy, it may be desirable to increase gradually the proportion of corn or similar grain in a self-fed mixture up to 60 per cent.[79] The rest of the mixture should be good-quality ground legume hay, with protein supplement as needed. When such a mixture is fed, it is advisable that the lambs be vaccinated against overeating disease, as stated in the next article.

In the West, where hay is usually cheap in comparison with grain, the allowance of grain is often restricted somewhat. However, if the lambs are to be sold on a market that pays a satisfactory premium for well-fattened animals, it will generally pay to feed 1.0 lb. or more of grain per head daily.[80] Lambs will not reach a satisfactory degree of fatness unless fed at least about 0.75 lb. of grain or other concentrates per head daily, after they have been brought on feed. On hay alone or even on hay and good corn silage, they will usually gain only 0.03 to 0.17 lb. per head daily and will grow rather than fatten.[81]

If it is desired to limit severely the amount of grain fed fattening lambs, it is best during the first half of the fattening period to feed them only hay or hay and silage, or else only a very small amount of grain, and then to finish them on a full feed of grain. This produces more rapid and cheaper gains than feeding half the usual amount of grain throughout the fattening period.[82]

1334. Death losses; enterotoxemia, or overeating disease.—Some death losses are unavoidable in the commercial fattening of lambs. However, the mortality should not exceed 3 to 4 per cent when healthy lambs are fed by experienced men. Much higher losses often occur if the lambs are not thrifty or if they are fed carelessly.

Enterotoxemia, or so-called "overeating disease," is generally the cause of most of the death losses in fattening lambs. This usually occurs only in lambs which have been on full feed for some time and which are being crowded on a heavy allowance of grain, so they will make rapid gains. The lambs affected are almost always the largest, fattest, most vigorous and greediest in the lot.

Sometimes the disease causes very sudden death, the lamb throwing back its head, staggering, falling to the ground, and dying in convulsions, as though from an apoplectic stroke. More commonly, the lambs live a few hours, showing typical brain symptoms, such as the head being thrown back or the lamb running in a circle or pushing against a fence. In many instances, lambs which have appeared thrifty the previous day are merely found dead in the morning. In only a few cases do the lambs recover.

Studies have shown that the disease is caused by a severe digestive disturbance in which bacteria called *Clostridium perfringens* produce toxins, or poisonous substances.[83] These dangerous toxins are absorbed from the digestive tract.

When deaths from the disease are occurring in a lot of fattening lambs, they can be stopped practically overnight by

withholding the grain. However, it is generally necessary to feed grain rather liberally to fattening lambs, or they will grow too large before they get fat enough to meet market demands.

To reduce the losses as much as possible when lambs are fattened rapidly, the following precautions must be observed. The utmost care must be taken to get the lambs on feed without producing digestive disturbances. All possible measures should be taken to prevent gorging. The grain must be distributed in the troughs so no lamb can get more than its share.

If lambs are self-fed, the grain should be mixed with sufficient bulky feed, preferably ground or chopped hay, to prevent digestive trouble. Even when lambs are hand-fed, it is wise to mix the grain with ground or chopped hay if they are being crowded on all the grain they will eat. When lambs are fed a mixture of grain and hay, it is best to let them also have as much long hay or silage as they care for.

Where a considerable number of lambs are being fattened, it is a good plan to sort out the fattest lambs as soon as they are well finished, and market them. If this is done, the amount of grain must be reduced and it must be remembered that the lambs which were ready first were the heartiest eaters.

Vaccination of feeder lambs with a bacterin largely prevents enterotoxemia during fattening. An anti-toxin, which is also made commercially, is also used on animals already affected with the disease.

Adding to the ration either flowers of sulfur or sodium bicarbonate (baking soda) has been recommended as a preventive of enterotoxemia.[84] However, often neither of these additions is effective in preventing the disease. In some tests an antibiotic supplement has reduced the occurrence of enterotoxemia. (1283)

1335. **Self-feeding.**—Often the men who fatten large numbers of western lambs use self-feeders to save labor. Self-feeding usually produces more rapid gains than hand-feeding, but it frequently results in greater death losses from overeating disease. Self-fed lambs generally require more grain and less hay per 100 lbs. gain than hand-fed lambs, and hence utilize less farm-grown roughage.

The safest method of self-feeding lambs is to feed, throughout the fattening period, a mixture of grain and some very bulky feed, especially ground or chopped alfalfa hay, or other good hay. It is best to grind the grain, so that it can be mixed more uniformly with the other feed, and so that it will not separate out of the mixture.

When the lambs are first started on grain, such a mixture as only 100 lbs. of grain with 300 lbs. of ground hay may be fed. The proportion of grain is then gradually increased until after 3 or 4 weeks a mixture of equal weights of grain and hay may be fed. Feeding a larger proportion of corn or other heavy grain is not desirable, for it may not increase the gains and it increases the danger of overeating disease.[85]

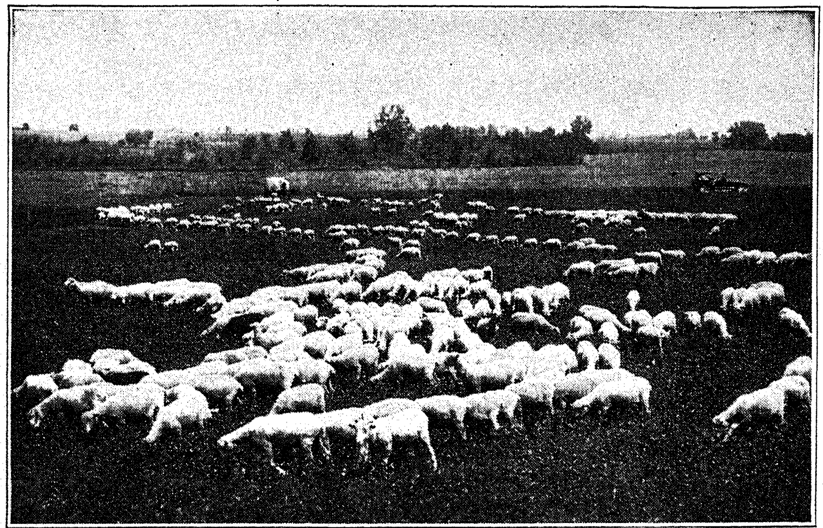
The self-feeders must be given proper attention, so they do not become clogged. When a suitable mixture is self-fed and the lambs have feed available at all times, so they do not get very hungry and then eat too much, the death losses may be no greater than in skillful hand-feeding.

The results from self-feeding a mixture of grain and ground or chopped hay are shown by 12 experiments in which a mixture of corn and alfalfa hay was self fed in comparison with hand-feeding corn and alfalfa hay separately.[86] The self-fed lambs ate an average of 1.4 lbs. corn and 1.5 lbs. hay and gained 0.37 lb. per head daily. The hand-fed lambs ate 1.2 lbs. corn and 1.5 lbs. hay and gained 0.34 lb. on the average. For each 100 lbs. gain the self-fed lambs required 372 lbs. corn and 406 lbs. hay, while the hand-fed lambs required 353 lbs. corn and 456 lbs. hay. In these experiments the feed cost of 100 lbs. gain at usual feed prices was fully as cheap for the self-fed lambs. Often, however, the gains are somewhat more expensive when lambs are self-fed.[87]

The use of chaffy grain screenings in place of ground or chopped hay in self-feeding lambs is advisable only if such low-grade material can be secured very cheaply. In New York tests such screenings were not worth their cost.[88] In Michigan trials oat hulls were worth about one-half as much as ground alfalfa hay, when used as the bulky feed for self-feeding lambs.[89] In Wyoming experiments, mixing dried beet pulp with the grain did not prevent death losses as well as did the use of ground alfalfa hay in the mixture.[90]

The danger from self-feeding is greatest when a heavy concentrate, like corn or barley, is fed alone in a self-feeder. Even when the lambs are brought on feed by careful hand-feeding and only then turned to self-feeders filled with such grain, heavy losses may occur.[91] There is less danger when the lambs, after being brought on feed by hand-feeding, are first self-fed such a bulky mixture as 3 parts oats and 1 part corn, and then are gradually changed to corn alone or corn and supplement.[92] However, sometimes heavy death losses occur even after lambs have been self-fed for several weeks on corn or other heavy feeds alone, with hay fed separately.

Lambs cannot be trusted to balance their ration if they are self-fed separately corn or other grain and a protein supplement like linseed meal or cottonseed meal. Sometimes they will eat about the proper amount of the supplement, but at other times they will take much more than is needed.[93] The supplement should therefore be mixed with the grain in the proper proportion.



A Band of Western Lambs Fattening in the Corn Belt

Many corn belt farmers make a practice of fattening one or more carloads of western lambs in the fall on aftermath, stubblefields, or standing corn.

1336. Fattening lambs on pasture in the fall.—Fattening lambs chiefly on pasture in the fall and then finishing them in dry lot, is a common practice with farmers who raise their own lambs and with many who buy western feeder lambs. Until cold weather sets in, the lambs may be grazed on stubble fields, aftermath in meadows, or rape or other pasture, with or without grain in addition. Rape is often seeded in small grain to increase the fall feed for lambs, the seeding not taking place until the small grain is well above ground, lest the rape grow so large as to reduce the yield of the grain crops.

Thrifty lambs placed on feed in the fall should be ready for sale in December or early in January. There is then usually a scarcity of good lambs on the market, since the grass-fat lambs have been marketed and those in winter feed lots are not yet finished.

Many lambs are fattened during the fall and winter on winter wheat [94] pasture in Kansas, Oklahoma, and other states. (583) Lambs will reach a good market finish on wheat pasture alone, if there is plenty of forage and the weather is suitable. There should always be a reserve supply of harvested feed on hand to carry the lambs over periods of bad weather, or for use if the wheat pasture becomes scanty before the lambs are fat.

In order to avoid digestive disturbances, one should be sure that the lambs are well filled with dry roughage before they are first turned on wheat pasture. Also, it may be a good plan to let them have access to some dry feed, such as sorghum stover, straw, or sorghum stubble, while they are on the wheat field. This reduces digestive trouble and helps prevent wheat poisoning. (179)

In the South fattening lambs make excellent gains on such winter pasture as ryegrass, rye, or oats, without grain feeding.[95] In the Imperial Valley of California lambs reached satisfactory finish, without grain feeding, on alfalfa pasture in which barley had been seeded in the fall to furnish additional winter feed.[96] Because of dog danger, the lambs were kept in a dog-proof corral at night and fed alfalfa hay.

Fattening lambs on standing corn has been discussed in a previous chapter. (700)

1337. Shrinkage in shipment; dressing percentage.—Fat lambs usually shrink 4 to 7 per cent in weight when shipped less than 150 miles to market. If they are shipped greater distances, the shrinkage may be as high as 8 to 10 per cent or more.

There is generally no need to make any decided change in the ration fed fattening lambs before shipment. It may be advisable to reduce the amount of grain somewhat the day before shipment, but the lambs may be allowed the usual amount of roughage. Oats are an excellent feed for sheep in transit, as they are bulky and not laxative. When sheep are marketed off pasture, especially rape pasture, shrinkage from scouring may be avoided by giving them hay or other dry feed for a day or two before shipment.

Based on market weights, fat lambs usually yield 47 to 51 per cent of dressed carcass. Exceedingly fat lambs or sheep may dress 60 per cent or even more, but such fat carcasses are very wasteful.

III.—Milk Goats; Angora Goats

1338. Milk goats.—Milk goats are of considerable importance in continental Europe, many families, especially of the poorer classes, relying on goats for their daily supply of milk. Much goats' milk is also used in Europe for the manufacture of certain types of cheese. Though milk goats have never become important in the United States, there are limited numbers in many states, the greatest number being in California. They are especially well suited for furnishing the milk supply for families living in small towns and the suburbs of large cities, or on fruit and truck farms where there is not enough feed available for a cow. A milk doe can often secure much of her feed from garden and kitchen waste or lawn clippings, or by grazing in such areas as vacant lots and rocky hillsides.

The milk of most breeds of milk goats averages 4.0 per cent or more in fat.[97] The fat globules are much smaller in size than those of cows' milk, and goats' milk forms a fine, soft curd during digestion. Goats' milk is white in color, as it has practically no carotene. Goats' milk produced under sanitary conditions, and if the buck is kept separate from the does, will not usually have an unpleasant "goat" flavor and odor, though the flavor is somewhat different than that of cows' milk.[98] One should always be sure that the goats are free from brucellosis, which causes undulant fever, or Malta fever, in humans.

Good pure-bred or high-grade does

yield 1,000 to 2,000 lbs. or more of milk a year. In Illinois tests one doe produced 3,045 lbs. of milk and 94 lbs. of fat in a year.[99] At peak of production one doe yielded 19.7 lbs. a day, and another 16.5 lbs. In a California study in a high-producing herd, the average yield was 7.5 lbs. of 4 per cent fat-corrected milk.[100] (999)

It is difficult to secure a uniform supply of milk throughout the year, as most milk goats freshen in spring and their lactation periods are somewhat shorter than those of cows.

Good milk goats require about the same amounts of feed as good cows per 100 lbs. of milk produced.[101] However, the cost of producing goats' milk on a commercial basis is higher than for cows' milk, chiefly because of the much greater amount of labor required per quart of milk.

In general, the same feeds and the same care and management that are successful with dairy cows and sheep are suitable for milk goats. From 6 to 8 goats can be kept on the feed required by a cow. A suitable ration is 1 to 2 lbs. of good concentrate mixture, with 3 lbs. hay or with 2 lbs. alfalfa or clover hay and 1.5 lbs. silage or roots. On pasture, 1 to 1.5 lbs. concentrates daily are usually needed by high producers. The concentrate mixture should be similar to those used for dairy cows.

When does are fed good alfalfa hay as the only roughage, merely a mixture of grain or grain and molasses produces about as good results as a more complex concentrate mixture.[100]

1339. Angora goats.—The raising of Angora goats for their mohair is important in certain southwestern range districts, especially in Texas. For the 5-year period, 1950–1954, an average of 2,414,000 Angora goats were sheared a year in the 7 principal producing states, the average clip of mohair being 5.3 lbs.[102]

The meat from the surplus goats is sold under the name of "chevon" and is appetizing if from a well-fattened young goat. In a Texas experiment Angora wethers a year old or older made considerably smaller daily gains than Rambouillet lambs during fattening.[103] The Angoras also required much more feed per 100 lbs. gain.

In the western states the goats are usually kept under range conditions, often grazing on rough land and utilizing browse that even sheep would refuse.[104] In cut-over districts, Angora goats are occasionally used for clearing land of brush, but the area must be heavily stocked and closely grazed to subdue the brush.

QUESTIONS

1. State 4 essentials of successful flock management.
2. What kinds of pasture are most commonly used for sheep in your region?
3. On what basis would you cull a flock of ewes?
4. Discuss the breeding of ewe lambs.
5. What factors determine the best date for lambing?
6. Under what conditions are twin lambs desirable?
7. Discuss the flushing of ewes.
8. State the most important points in feeding and caring for the ram.
9. How should ewes be fed in the fall?
10. Discuss the feeding of pregnant ewes in winter.
11. Describe the care of ewes at lambing time.
12. State the most important points concerning the feed and care of ewes after lambing.
13. State the important points concerning the feeding and care of young lambs.
14. How much milk a day do ewes of the common breeds yield?
15. When is it advisable to creep-feed lambs?
16. What are the best times to market farm-raised lambs in your region?
17. What are spring lambs and where are they chiefly produced?
18. Approximately how much hay and concentrates does it require to carry a breeding ewe through the winter?
19. State 5 important factors affecting the net income from sheep.
20. Describe a method by which stomach worms and other internal parasites can be controlled.
21. How are sheep handled on the western ranges?
22. Describe any methods of fattening western lambs that are used in your district.

23. What kind of feeder lambs would you purchase to fatten for the market?
24. In commercial lamb fattening, how much gain is secured per head daily, and how much concentrates and roughage are required per 100 lbs. gain?
25. State a good ration for fattening lambs, adapted to your local conditions.
26. How should fattening lambs be started on feed?
27. Discuss the proportions of concentrates and roughage for fattening lambs.
28. How may losses from overeating disease be avoided?
29. Discuss the advantages and disadvantages of self-feeding fattening lambs.
30. If lambs are fattened on pasture in the fall in your region, describe the methods used.
31. What is the usual percentage of shrinkage of fat lambs on shipment to market? What is the usual dressing percentage?
32. State the most important facts concerning the feeding of milk goats.
33. In what districts of this country are Angora goats important?

REFERENCES

1. Harper, Ind. Bul. 344.
2. Rather and Harrison, Mich. Cir. Bul. 189; Fuelleman, Burlison, and Kammlade, Ill. Bul. 496, and Jour. Amer. Soc. Agron., 36, 1944, pp. 849–858.
3. Massey, Ga. Bul. 200; see also: Ky. Rpt. 1941; Hunt, Md. Bul. 378.
4. Kammlade, Sheep Science, pp. 461–462.
5. Joseph, Mont. Bul. 242; Ore. Bul. 350; Terrill and Stoehr, U.S.D.A., Jour. Anim. Sci., 1, 1942, pp. 221–228.
6. Branaman, Ill., Jour. Agr. Res., 60, 1940, pp. 473–486; Hunt, Md. Bul. 380.
7. Briggs, N.D. Bul. 285; Longwell. N.D. Bul. 316; S.D. Rpts. 1940, 1941; Jacob, Tenn. Rpt. 1933; Hicks, Can. Expt. Farms, Agassiz Farm, Rpt. Supt. 1923; Fortier, Can. Expt. Farms, LaFerne Sta., Rpt. Supt. 1923; Phillips, Welsh Jour. Agr., 4, 1928, pp. 121–41; see also: Willman, Morrison, Brown, and F. C. Huyck and Sons, N.Y. State Col. of Agr., Cornell Misc. Bul. 6, 1948.
8. Wilson, Cal. Rpt. 1921; McKenzie and Phillips, Mo. Bul. 310; Chittenden and Walker, Mont., Nat. Wool Grower, 27, 1937, pp. 24, 25; Carlyle, Humphrey, and Kleinheinz, Wis. Rpt. 1907; Humphrey and Kleinheinz, Wis., information to the author; Terrill, U.S.D.A., Jour. Anim. Sci., 3, 1944, pp. 434–435; Kammlade, Sheep Science, pp. 294–295.
9. Bell, Ohio Bul. 705.
10. Joseph, Mont., Nat. Wool Grower, 16, 1926, No. 4, pp. 19–21; Fleming, Nev. Rpt. 1933.
11. N.C. Rpt. 1938–40; Marshall and Potts, U.S.D.A. Bul. 996; Marshall, Trans. High. Agr. Soc., Scotland, 1908; Hammond, Jour. Min. Agr., Gr. Britain, 48, 1941, pp. 77–79; Underwood and Shier, Jour. Dept. Agr., West Australia, 18, 1941, pp. 13–21; see, however, Briggs et al., Okla. Bul. B-255.
12. Brown, Noland, and Douglas, Ark. Farm Res., 2, 1953, No. 1; Bell and Smith, Kan. Cir. 283; Dutt, Ky., Jour. Anim. Sci., 12, 1953, pp. 515–523; VanderNoot, Reece, and Skelly, N.J., Jour. Anim. Sci., 8, 1949, pp. 583–589; Zenzke, Ohio, Amer. Jour. Vet. Res., 14, 1953, pp. 411–414; Price and Hardy, Texas, Jour. Amer. Vet. Med. Assoc., 123, 1954, pp. 195–197; see also: Gassner, Colo. Farm and Home Res., 1, 1950, No. 4.
13. Dutt and Bush, Ky., Jour. Anim. Sci., 14, 1955, pp. 885–895.
14. Ore. Bul. 477; Eaton and Simmons, U.S.D.A., Sci. News Letter, Dec. 12, 1953.
15 Dutt and Hamm, Ky., Jour. Anim. Sci., 14, 1955, p. 1245; Landers, Ore., Feed Bag, September, 1953; Hulet et al., Wis. Buls. 511, 517.
16. Miller, Hart, and Cole, Cal. Bul. 673; Snell, La., Amer. Soc. Anim. Prod., Proc. 1933; Neale, New Mex. Bul. 388; Bell, Ohio Spec. Cir. 21 and Ohio Bimo. Bul. 118; Muth, Shaw, and Richards, Ore. Cir. Information 277; Hammond, Proc. Nutr. Soc., Great Britain, 2, 1944, p. 8; Wallace, England, Jour. Agr. Sci., 38, 1949, pp. 367–401; Thomson and Thomson, Scotland, British Jour. Nutr., 2, 1948–49, pp. 290–305.
17. Blakeslee, Mich. Spec. Bul. 255; Weber and Loeffel, Nebr. Bul. 250; Neale, N. Mex. Bul. 388; Jennings, N.D. Bul. 186.
18. Dowe and Klosterman, S.D. Rpt. 61; McCarty and Weakly, S.D. Rpt. 63.
19. Cox and Reed, Kan. Bul. 316; Md. Rpt. 1945; Weber and Loeffel, Nebr. Bul. 250; Lacey et al., Wis. Cir. 366.
20. Kammlade, Ill. Rpts. 1934, 1935, 1936.
21. Miss. Rpts. 62, 64.
22. Guyer and Dyer, Mo. Res. Bul. 558.
23. Wilson, Johnson, and Wright, S.D. Bul. 388.
24. Ky. Rpts. 62, 63, 65, 66; Blakeslee, Brown, and Wells, Mich. Quar. Bul., 20, 1937, No. 2; Mich. Rpt. 1938; Joseph, Mont. Bul. 247.
25. Williams et al., Canada, Sci. Agr., 30, 1950, No. 1.
26. VanHorn et al., Mont. Mimeo. Rpts. 56, 63, 68; Mont. Cir. 206; see also: Darrock, Nordskog, and VanHorn, Jour. Anim. Sci., 9, 1950, pp. 431–445; N. Mex. Rpt. 1948.
27. Whitcomb, Harris, Cook, and Williamson, Utah Farm and Home Sci., 12, 1951, No. 3.
28. McCarty and House, S.D. Rpt. 64.
29. Bell and Bradford, Ohio Farm and Home Res., No. 250; Warnick, Rutland, and Bonnicksen, Ore. Cir. of Inform., Oct., 1952; Mowery, Schaffner, and Henning, Penn. Prog. Rpt. 74.
30. Fleming, Brennen, Smith, and Bruce, Nev. Bul. 151; Pingrey, New Mex. Bul. 325; Hochmuth and Gorton, Ore. Bul. 381; Broadbent, Utah Farm and Home Sci., 7, 1946, No. 2.
31. Bell, Ohio Spec. Cir. 21; Utz, Ohio Bimo. Bul. 119.
32. Kleinheinz, Wis. Rpts. 1902, 1907, and information to the author.
33. Phillips and Dawson, U.S.D.A. Cir. 538; Wilson, West Va. Bul. 342.
34. Wilson, Cal. Rpt. 1922.
35. Grimes, Sewell, and Cottier, Ala. Cir. 69; Horlacher, Ky. Rpts. 1926, 1941, 1942; Hunt, Meade, and Carmichael, Md. Bul. 417; Hinman, Willman, and Schutt, N.Y. (Cornell) Rpts. 1930, 1931, 1932; Bell, Ohio Bul. 402; Ont. Agr. Coll. Rpt. 1919.

36. Burris and Baugus, Ark., Jour. Anim. Sci., 14, 1955, pp. 186–191; Ark. Farm Res., 3, 1954, No. 2.
37. Ritzman and Davenport, N.H. Bul. 232.
38. Neidig and Iddings, Id., Jour. Agr. Res., 17, 1919, pp. 19–32; Ritzman, N.H., Jour. Agr. Res., 8, 1917, pp. 29–36; Ritzman, N.H. Tech. Bul. 14; Carlyle, Fuller, and Kleinheinz, Wis. Rpt. 1904.
39. For a review of the many investigations on pregnancy disease, see: Sampson, Ill. Bul. 524.
40. Md. Bul. A-78.
41. Willman, Loosli, Asdell, Morrison, and Olafson, N.Y., Jour. Anim. Sci., 4, 1945, pp. 128–131; Willman, N.Y. Farm Research, 13, 1947, No. 4; Whiting, Willman, and Loosli, N.Y., Jour. Anim. Sci., 8, 1949, pp. 234–242; see also: Culik et al., Mich., Jour. Anim. Sci., 10, 1951, pp. 1006–1016; Bacigalupo et al., Mich., Jour. Anim. Sci., 11, 1952, pp. 609–620.
42. Ore. Buls. 461, 477, 491.
43. Kammlade, Sheep Science, pp. 312–313.
44. Weir, Cal., Jour. Anim. Sci., 9, 1950, p. 671; Garrigus and Johnson, Ill., Jour. Anim. Sci., 8, 1949, pp. 619–620; Culik et al., Mich., Jour. Anim. Sci., 8, 1949, p. 616.
45. Fleming and Young, Nev. Rpts. 1930, 1931; Ritzman and Benedict, N.H. Tech. Bul. 43; Phillips, Welsh Jour. Agr., 4, 1928, pp. 121–141.
46. Ind. Rpt. 1936.
47. Ind. Rpt. 1936; Ky. Rpts. 1940, 1941, 1944, 1945.
48. Grimes, Sewell, and Cottier, Ala. Cir. 69; Harper, Ind. Bul. 344; King and Harper, Ind. Bul. 353; Harper, Ind., Amer. Soc. Anim. Prod., Proc. 1933; Dyer and Weaver, Mo. Bul. 425; Jacob, Tenn. Rpts. 1932, 1938; Kincaid, Litton, and Hunt, Va. Rpt. 1946; Bohstedt and Darlow, Wis. Bul. 420; see also: Briggs, Okla. Rpt. 1936–38.
49. Garrigus, Ky. Bul. 567.
50. Fleming, Miller, and Young, Nev. Rpts. 1931, 1933.
51. Potts, U.S.D.A. Farmers' Bul. 2058.
52. Hammond, Ohio Bul. 340.
53. Ky. Rpt. 1943, Dyer and Weaver, Mo. Bul. 425; N.D. Bul. 306.
54. S.D. Rpt. 64; see also: Leveck, Miss. Cir. 131.
55. Torell and Weir, Cal. Agr., 8, 1954, No. 12.
56. Newmann, Mabry, and Gifford, Ark. Bul. 501; Miller, Cal. Cir. 348; Kellogg, Ga. Exten. Bul. 372; Hodgson et al., Id. Bul. 272; Phillips and Rudd, Ky. Bul. 427; Wilford and Garrigus, Ky. Bul. 578; Leveck, Miss. Bul. 440; Graham, Egli, and Ulberg, Miss. Farm Res., 17, 1954, No. 2; Ross and Dyer, Mo., Jour. Anim. Sci., 6, 1947, p. 495; N.C. Rpt. 1941; Lindgren and Potter, Ore. Bul. 265; Hansard and Hobbs, Tenn. Rpt. 1948; Carter, Copenhaver, and Kincaid, Va. Rpt. 1950–53; Cunningham and Livesay, West Va. Bul. 330; see also: Blakeslee, Tesar, and Morrow, Mich., Jour. Anim. Sci., 14, 1955, p. 1235; Bell and Kunkle, Ohio Bul. 725.
57. Wing, Savage, and Tailby, N.Y. (Cornell) Bul. 309; Henning et al., Penn. Buls. 255, 293, 464, 480; Kean and Henning, Penn., Jour. Anim. Sci., 8, 1949, pp. 362–372.
58. Pope et al., Wis. Cir. 470; see also: Smith and Mayo, Ind. Bul. 591.
59. Nodland and Pond, Minn. Bul. 382.
60. Kepner, N.Y., mimeo. rpt.; see also: Morison, Ohio Bimo. Bul. 163.
61. Severson, Penn. Bul. 144.
62. For detailed discussions of range sheep production, see: Hultz and Hill, Range Sheep and Wool; Sampson, Live Stock Husbandry on Range and Pasture; Cooper, U.S.D.A. Farmers' Bul. 1710; Pickrell and Stanley, Ariz. Bul. 134; Burdick, Colo. Bul. 467; Favre and Phinney, Id. Bul. 228; Saunderson and Vinke, Mont. Bul. 302; Heady, Clark, and Lommasson, Mont. Bul. 444; Gray and Baker, Mont. Bul. 478; Fleming, Brennen, Smith, and Bruce, Nev. Bul. 151; Pingrey, New Mex. Bul. 204; Hochmuth and Gorton, Ore. Bul. 381; Esplin et al., Utah Buls. 204, 277, 292; Broadbent, Blanch, and Thomas, Utah Bul. 325; Vass and Pearson, Wyo. Bul. 156.
63. Cover, Mackey, et al., Texas Bul. 661.
64. Dean and Potter, Ore. Bul. 218.
65. Kammlade, Ill., mimeo. rpt.; Cox and Sloan, Kan. Rpts. 1936–38, 1938–40; Hunt, Md. Bul. 379; Pingrey, New Mex. Bul. 285; Neale and Koger, New Mex. Bul. 335; Willman and Morrison, N.Y. (Cornell) Rpts. 1932, 1933; Bell, Ohio Buls. 674, 695; Jordan, S.D., mimeo. rpt.
66. Neale, New Mex. Bul. 375.
67. Maynard, Morton, and Osland, Colo. Bul. 379; Rinehart, Hickman, and Johnson, Id. Buls. 194, 205, 220; Kammlade, Ill. Rpt. 1936; Cox, Kan. Rpt. 1936–38; Jordan and Peters, Minn. Bul. 272; Bell, Ohio Buls. 579, 592; Mackey and Jones, Tex. Bul. 465; Maynard, Esplin, and Boswell, Utah Bul. 238.
68. Brown, Mich. Spec. Bul. 233; Bell, Ohio Bul. 402; Bell, Kaufman, and Kunkle, Ohio Buls. 705, 725; see also: Keith and Henning, Penn. Bul. 288.
69. Morton, Colo. Rpt. 1931; Foster, Colo. Tech. Bul. 10; Coffey, Ill. Bul. 167; Ky. Rpt. 1926; Jones et al., Tex. Rpt. 1933; O'Mary et al., Wis., Jour. Anim. Sci., 11, 1952, pp. 656–673.
70. Neale and Bell, New Mex. Bul. 309; New Mex. Rpt. 1948.
71. Wright, Mich. Spec. Bul. 284.
72. Burdick, Colo. Farm Bul., 7, 1945, No. 5.
73. Willman and Morrison, N.Y. (Cornell) Bul. 691.
74. Willman, Embry, and Morrison, N.Y. (Cornell) Rpt. 1950 and mimeo. rpt.
75. Esplin, Colo. Farm and Home Res., 3, 1953, No. 6; Quayle and Paules, Wyo. Cir. 44.
76. Davison, Keith, and Hickman, Id. Bul. 281; Coffey, Ill. Bul. 167; Skinner, King, Starr, and Vestal, Ind. Buls. 221, 234, 256, 263; Culbertson, Iowa Rpt. 1945, Part 1; Cox and Connell, Kan. Bul. 264; Gramlich, Nebr. Bul. 170; Blakeslee and Brown, Mich. Quar. Bul., 17, 1935, No. 4; 23, 1940, No. 2; Alexander, Nebr., mimeo. rpt.; Botkin and Paules, Wyo. Mimeo. Cir. 44.
77. Esplin, Colo. Farm and Home Res., 3, 1953, No. 6; Culbertson et al., Iowa A.H. Leaflets 174, 178, 181; Cox, Kan. Tech. Bul. 65; Bell and Hughes, Kan. Rpt. 1950–52; Bell, Cox, and Hughes, Kan. Cir. 283; Blakeslee and Brown, Mich. Quar. Bul., 30, 1947, No. 2.
78. Cox, Kan. Tech. Bul. 65; see also: Phillips, Hardin, and Thomas, Ky., Jour. Anim. Sci., 10, 1951, pp. 424–427.
79. Culbertson et al., Iowa A.H. Leaflets 174, 178, 181; Peters and Jordan, Minn. Farm and Home Sci., 4, 1947, No. 3.
80. Fleming, Nev. Bul. 106; Simpson, New Mex. Bul. 79; Hackedorn, Singleton, and Sotola, Wash. Bul. 351.

81. Hickman, Id., mimeo. rpt.; King and Harper, Ind. Bul. 360; Holden, Nebr. Bul. 194; Fleming, Nev. Bul. 106; Richards, Ore. Bul. 370; U.S.D.A., Bur. Anim. Indus., Rpt. 1933.
82. Skinner, King, and Vestal, Ind. Buls. 234, 256, 263.
83. Dougherty and Cello, N.Y., Cornell Vet., 39, 1949, pp. 403–413; Dain, Neal, and Dougherty, N.Y., Jour. Anim. Sci., 14, 1955, pp. 930–935.
84. Esplin, Colo. Farm and Home Res., 4, 1954, No. 6; Garrigus, Kammlade, Boley, and Hardenbrook, Ill., Jour. Anim. Sci., 12, 1953, pp. 474–479; Culbertson and McDonald, Iowa Rpt. 1949; Bell, Cox, Holland, and Erhart, Kan., Jour. Anim. Sci., 12, 1953, p. 908.
85. Esplin, Colo. Farm and Home Res., 3, 1953, No. 6; Blakeslee and Brown, Mich. Quar. Bul., 30, 1947, No. 2.
86. Maynard, Morton, and Osland, Colo. Bul. 379; Kammlade, Ill. Cir. 523; Brown and Blakeslee, Mich. Spec. Bul. 303; Baker, Nebr., mimeo. rpt.; Darlow, Okla. Bul. 228.
87. Morton, Osland, and Tom, Colo. Press Bul. 91; Hickman and Rinehart, Id. Bul. 270; Bell and Erhart, Kan. Cir. 283; Bell and Hughes, Kan. Rpt. 1950–52; Jordan and Peters, Minn. Bul. 272; Bohstedt, Wis. Bul. 421; Ingraham, Wyo. Bul. 257.
88. Willman and Morrison, N.Y. (Cornell) Rpts. 1932, 1933.
89. Brown and Blakeslee, Mich. Spec. Bul. 303.
90. Ingraham, Wyo. Bul. 257.
91. Kammlade, Ill. Bul. 338; Brown, Mich. Quar. Bul., 16, 1933, No. 1; Bell, Ohio Bimo. Bul. 151.
92. Skinner and King, Ind. Buls. 273, 282, 296.
93. Skinner and King, Ind. Buls. 273, 282, 296; Paterson, Kan. Cir. 108; Brown, Mich. Quar. Bul., 16, 1933, No. 1.
94. Cox, Kan., Jour. Anim. Sci., 6, 1947, p. 493; Bell and Hughes, Kan. Rpt. 1950–52; Noble, Stephens, Humphrey, and MacVicar, Okla. Misc. Pub. MP-34.
95. Leveck and Pingrey, Miss., Jour. Anim. Sci., 10, 1951, p. 1071.
96. Ittner and Weir, Cal. Agr., 8, 1954, No. 1.
97. Ormiston and Gaines, Ill., Jour. Dairy Sci., 27, 1944, p. 244; Holmes, Lindquist, and Greenwood, Mass. Bul. 428; Gamble, Ellis, and Besley, U.S.D.A. Tech. Bul. 671; Lythgoe, Jour. Dairy Sci., 23, 1940, pp. 1097–1108.
98. New Mex. Rpt. 61.
99. Ill. Rpts. 1938–47, 1948.
100. Mead, Peck, and Cole, Cal. Agr., 9, 1955, No. 12.
101. Brody, Sandburg, and Asdell, Mo. Res. Bul. 291; Brooks, Cornell Univ., Ph.D. thesis.
102. U.S.D.A., Agr. Statistics, 1955.
103. Miller, Jones, and Burt, Tex. Bul. 631.
104. Willingmyer et al., U.S.D.A. Misc. Cir. 50; Williams, U.S.D.A. Farmers' Bul. 1203; Nelson, Ore. Bul. 289; Lush and Jones, Tex. Bul. 320; Hamilton, Tex. Bul. 444.

CHAPTER XXXII

HORSES AND MULES—GENERAL PROBLEMS

I. Factors Influencing the Work Done

1340. Importance of economical feeding and care.—Although tractors and trucks have largely replaced horses and mules in the United States, in some countries they are still very important. In this country there is much interest in saddle horses and other light horses.

The discussions in this volume concerning the nutrient requirements and the feeding and care of horses deal, of necessity, chiefly with work horses. This is because nearly all of the scientific experiments with horses have been with draft horses, rather than with light horses.

However, the same general principles apply to light horses as to horses used for draft. The special points in the feeding and care of light horses are treated in the following chapter. (1376–1377)

The importance of efficient feeding of horses and mules is shown by the fact that it is often possible to save 10 to 20 per cent of the usual feed cost, with no injury and in some cases even a benefit to the animals. Also, the animals must have proper feed and care if they are to remain useful over a period of many years.

Before studying the methods of feeding and caring for horses and mules, we will briefly consider the various factors which influence the amount of work they can perform. Most of the following discussions refer particularly to horses, since nearly all of the scientific trials have been conducted with them. The same feeds may be used for mules, however, and the same principles of feeding and care apply to them. (1358)

1341. Work done by horses.—The work which horses can do depends on their weight, their muscular development, and their endurance. At steady and continuous work for 10 hours a day, the pull (or draft) for a horse should not be more than one-eighth to one-tenth its weight. For example, a 1,600-lb. horse should not be required to exert an average pull of more than 160 to 200 lbs.

For a brief interval a well-trained horse can do 10 times the normal rate of work, and can exert a pull nearly as great as his weight. A few can momentarily exert a pull even greater than their weight. The horse greatly excels all types of engines and motors in this capacity for overload.

This reserve power of a good team is of great importance in their ordinary work. For example, it may require more than 10 times as great a pull to start a loaded wagon as it will take to haul it after it is once in motion. Also, this reserve power is essential in drawing loads over uneven roads and up steep grades, or under other conditions where great effort is needed for short periods.

This great reserve power of horses is probably due to the fact that they are able to store much greater amounts of glycogen in their muscles and other tissues than other farm animals.[1] This large store of glycogen serves as an immediately available source of energy for muscular work. Horses also have a much higher rate of metabolism per unit of weight when idle than other farm animals, and about double that of man. This high rate of metabolism helps explain the capacity of the horse for work.

In measuring the rate at which horses perform work, the unit called the *horse power* is used. This is the performance of 33,000 foot-pounds of work per minute. (One foot-pound is the amount of work done in lifting one pound one foot against the force of gravity.) A horse weighing 1,500 to 1,600 lbs. is able to work steadily at the rate of approxi-

mately one horse power.[2] An ox can draw about as heavy a load as can a horse of the same weight, but ordinarily at only two-thirds the speed. The work a man can do is usually from one-tenth to one-sixth of a horse power, but for a minute or two he can exert a full horse power or even more.

The great power that can be exerted by horses is shown by a championship record made by a 4,450 lb. team in a horse-pulling contest. In such contests specially constructed dynamometers are used, in which the power to pull the dynamometer can be adjusted at various amounts. This team pulled the dynamometer the full distance required when set at a pull of 3,900 lbs. This pull was equivalent to starting a load of more than 25 tons for 20 consecutive times on a good pavement.

1342. Factors affecting the work performed.—Weight is the most important single factor that determines the amount a draft horse can pull. However, as the weight of draft horses increases, the pull they can exert per 100 lbs. live weight decreases somewhat.[3]

To perform work most efficiently, horses should have energetic but calm dispositions, and they must be well trained and driven skillfully and steadily. A nervous, excitable driver cannot get the utmost from his team. Among horses of the same weight, those with the greater heart girth and compact, muscular build are able to exert a greater pull. Horses must also be in proper flesh to do their best.

A horse cannot do the maximum amount of work unless the harness fits properly. It is especially important to have the collar fit well, in order to avoid sore shoulders. Also, when horses must be worked hard during rainy weather, the harness should have hame housing to keep the collar and shoulders dry. When properly shod, horses are able to pull more than when unshod.

The kind of roadbed is important in determining how heavy a load a horse can draw. While only 25 to 50 lbs. of draft are required after the load is started to haul a load of a ton (including weight of wagon) on a level pavement made of concrete or brick, the draft on a common earth road is 75 to 225 lbs. or more per ton.[4]

Many years ago extensive respiration experiments were conducted by European scientists to determine the nutrients required by horses for various types of work, and the effect of speed and other factors.[5] Later, similar studies were carried on by Brody at the Missouri Station [6] and Ritzman at the New Hampshire Station.[7] These investigations showed that horses perform work most efficiently when walking at a speed of 2 to 2.5 miles per hour. At a trot, nearly twice as much energy is required per mile of travel as at a walk.

The efficiency continues to become less as the speed increases, until when worked at a speed of 11.25 miles an hour, a horse can accomplish less than one-tenth of the amount of work he can perform at a moderate pace.

While a pound of additional load makes but little difference to a draft horse, with running horses the requirement of speed makes it necessary that the weight carried (rider and saddle) be as small as possible. An ounce of additional load may make a difference of a yard or more in half a mile of running.

In going up a grade, a horse must not only propel his body and the load over the ground, but also he must raise them against the force of gravity. Therefore more energy is required. For example, in ascending a grade of 10.7 feet in 100 feet, a horse expends three times as much energy per mile as when traveling on a level road. In going down a hill, if the slope is too steep the horse must spend energy in bracing himself and the load against too-rapid a descent.

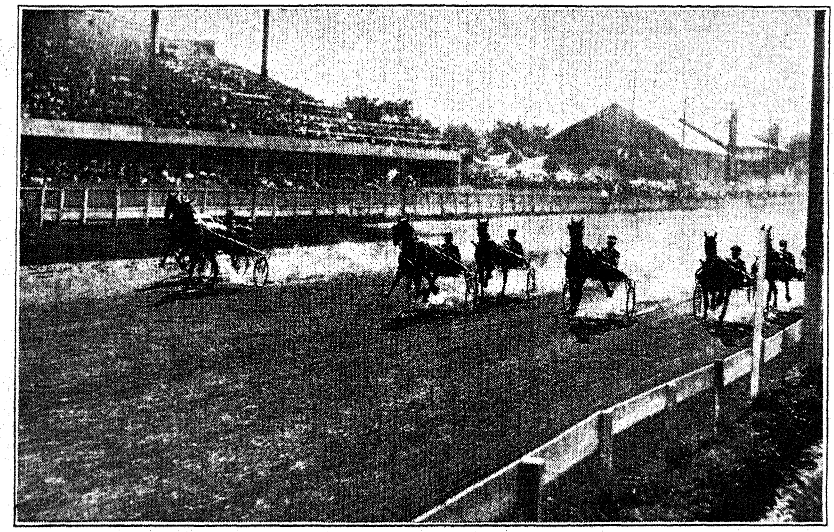
1343. Best size of horse for farm work.—The best size of horses or mules for any particular farm will depend on several factors. Farmers on level farms with large fields usually prefer heavier work animals than do farmers on hilly farms where the fields are small. On heavy soil where the draft of tillage implements is great, large size in work ani-

mals is advantageous. However, on sandy soil most farmers favor animals which are not too heavy.

Lighter horses, which can be kept more cheaply, are usually more active and will perform just as much of many kinds of farm work as extremely heavy horses. For the tillage operations which require much power, such as plowing with gang plows, the necessary power can be secured by using moderate-weight horses in teams of 3 to 5 animals, or even more.

worked at the usual rates, they converted into actual work about 20 to 25 per cent of the energy they expended during the time they were working.[9] The rest of the energy is converted into heat and is lost, so far as useful work is concerned.

However, to gain a true idea of the efficiency of the horse as a source of power, we must compute his over-all efficiency for the entire day of 24 hours. This is the percentage of the total or gross energy in his daily feed, which he



Speed Decreases the Work that Can Be Performed

A pound of additional load makes but little difference to a draft horse, but with the race horse the load must be made as light as possible.

is able to convert into useful work. Based on the amount of feed required per day, a 1,500-lb. horse working 8 hours a day at a rate of 1 horse power will have an over-all efficiency of about 8.9 per cent.

If large and small horses do amounts of work which are in proportion to their weights, their efficiencies in performing work will be equal, according to Missouri experiments.[8] On the other hand, if a large horse is not worked in such a manner as to perform an amount of labor which is proportional to his size, his efficiency will be lowered.

1344. Efficiency of the horse as a motor.—It is of interest to compare the efficiency of horses, in converting into useful work the nutrients they consume, with the efficiency of farm tractors. In Missouri experiments when horses

However, farm horses do not work every day, though they must eat every day. Therefore the over-all efficiency for the entire year is much lower than for a 24-hour period in which the horse does a good day's work. On the average, the yearly over-all efficiency of farm horses, which usually work only about 800 to 1,000 hours a year, is about 2 to 3 per cent. Obviously, any factor which in-

creases the number of hours of work a horse does during the year increases his over-all efficiency and reduces the actual cost of his labor per hour, since less of his feed will then go for maintaining him when idle.

When operated at maximum efficiency, gasoline tractors convert about 13 per cent of the energy of the fuel into the work of draft.[10] In comparing this with the efficiency of 8.9 per cent for horses in converting the energy of their feed into draft when working a full day, we must consider the following: The horse is supplied with feed in crude form, and a considerable part of it is indigestible and therefore of no value in the production of work. The gasoline or kerosene tractor, however, is not supplied with crude fuel, but with highly-refined fuel from which the waste portions have been removed. Moreover, the horse repairs his body continuously, while the tractor cannot replace the daily wear of its parts.

II. Nutrients Required by Horses

1345. Nutrients required by various classes of horses.—The chief requirement of an animal doing muscular work is a liberal supply of total digestible nutrients or net energy, as has been shown in Chapter X. For the performance of work, an animal needs but little more protein than when it is idle. Also, the requirements for minerals and vitamins are not appreciably increased by hard labor. (311) Rations that are relatively low in protein and that have only a moderate supply of minerals and vitamins are therefore entirely satisfactory for mature work horses or mules.

The chief need of mature idle horses is for heat to maintain the body temperature, and only a small amount of net energy is required. (235, 241–244) Also, the requirements for protein, minerals, and vitamins are low. Mature idle horses can therefore be fed rations that consist largely of such cheap feeds as straw or corn stover, which are low in net energy and in protein, but which produce much heat in the body.

Because of their more nervous disposition, horses allowed to move about considerably have a somewhat higher maintenance requirement than cattle or other farm animals, in proportion to their size.[11]

Brood mares need liberal amounts of protein, minerals, and vitamins during pregnancy. (288) When they are nursing foals, their requirements for these nutrients are still greater. (300) Colts likewise need a much greater proportion of protein than do mature work horses, and also more calcium, phosphorus, and vitamins.

1346. Morrison feeding standards; rations for horses.—In the Morrison feeding standards, which are presented in Appendix Table III, the requirements of the various classes of horses are stated. It will be noted that these standards show the amounts of dry matter, digestible protein, and total digestible nutrients required per head daily by horses of various live weights and of the various classes. Allowances of calcium, phosphorus, and carotene are also stated. Amounts of net energy are recommended for those who wish to compute rations according to the net-energy method.

In these standards the allowance of total digestible nutrients for a horse at hard work is about double that for an idle horse of the same weight, while there is much less difference in the dry matter. This means that the ration must consist more largely of grain and other concentrates as the work becomes harder. The approximate amounts of hay and concentrates that should be fed to horses that are at hard, medium, and light work and to those which are idle are stated in the paragraphs preceding Appendix Table III.

Horses probably differ more in temperament and in individual feed requirements than do other classes of stock. Therefore a feeding standard can serve only as a general guide as to the amount of grain any particular horse will need to keep it in proper condition.

Many different rations are suggested in Appendix Table VII for horses of various classes. These are suited to condi-

tions in various parts of the country and should be helpful in selecting balanced rations that are economical under the local conditions.

1347. Digestibility of feeds by horses.—Horses digest their feed somewhat less completely than do ruminants, but the difference is not marked, except for low-grade roughages, such as straw or poor-quality hay.[12]

Too few digestion trials have been conducted with horses to warrant separate tables of digestible nutrients for them. Therefore, in computing rations for horses, values must be used which are based upon digestion trials with ruminants, such as the figures for digestible nutrients given in Appendix Table I.

The Morrison feeding standards for horses are designed for use with these digestible nutrient values, and allowances have been made for the lower digestibility of roughages by horses. Rations will therefore be satisfactory if computed according to these standards and according to the rules for feeding concentrates and roughages that are given in Appendix Table III, immediately preceding the feeding standards.

Investigations showed many years ago that moderate work, even immediately after a horse had eaten, tends to increase the digestion and absorption of nutrients.[13] Severe labor may, however, retard digestion. Contrary to some statements, reasonable exercise does not hasten the passage of food from the stomach into the small intestine.

1348. Roughage requirements of horses.—Under usual conditions it is advisable to feed approximately the amounts of hay or other roughage advised in the paragraphs preceding Appendix Table III and in Appendix Table VII. However, when hay is relatively high in price in comparison with grain, the amount of roughage can be reduced somewhat.

For example, in Connecticut trials hard-worked horses were kept in good condition on only 8 lbs. of hay per head daily, plus a sufficient allowance of grain.[14] In Texas tests ponies grew satisfactorily on a ration of corn, dried beet pulp, and purified casein, plus minerals and complete vitamin supplements, but with no hay or other roughage except the beet pulp.[15]

In World War II German and Russian army horses in active service were satisfactorily fed compressed cakes or cubes made of mixtures of concentrates and ground roughage, in order to save space in transportation.[16]

As is emphasized in the next chapter, horses at work and light horses should not be allowed to eat all the very palatable hay that they will consume, for they may eat so much that it will be detrimental.[17] (1361)

From the limited data available, it seems that it will take 2.5 to 3.0 lbs. or more of hay to equal 1.0 lb. of corn or oats for the production of work.[18] For maintaining an idle horse in winter, hay will have a higher value, and it will probably take only 1.5 to 2.0 lbs. of hay to equal 1.0 lb. of grain in value.

1349. Requirements for protein.—It will be noted that the Morrison feeding standards recommend 0.6 to 0.8 lb. digestible protein per day for a 1,000-lb. idle horse. For horses at work somewhat larger amounts are advised, depending on the severity of the work. These recommendations are considerably lower than the amounts of digestible protein recommended in the older standards, such as the Wolff-Lehmann or the Armsby standards.

In various experiments rations having even less protein than advised in the Morrison standards have been fed successfully to idle horses and to horses at work.[19] Therefore, when protein-rich feeds are unusually expensive, mature idle horses or work horses can undoubtedly be fed for considerable periods on less protein than stated in the standards. However, for continued feeding over a long time, the author would not advise less protein than is recommended in the standards. It must be borne in mind that the digestibility of a ration may be decidedly decreased if the protein content is too low. Therefore, merely to secure efficient utilization of feed, it is not ad-

visable to use rations extremely low in protein.

In New York experiments with mature work horses, a mixture of 900 lbs. cracked corn and 100 lbs. crushed oats was just as satisfactory as one having more protein, when fed with timothy hay cut reasonably early.[20] If the hay had been late-cut timothy hay, low in protein, the results probably would have been much less satisfactory on the combination of corn and timothy hay with the small amount of oats.

1350. Mineral requirements.—Mature work horses, with the possible exception of brood mares, do not require the addition of any minerals, except common salt, to ordinary rations that contain a normal amount of good hay. This is because their needs for calcium and phosphorus are relatively low.[21]

In Iowa trials with mature work horses and in New York tests with growing colts, there was little or no benefit from adding a mineral mixture supplying calcium and phosphorus to properly balanced rations which had plenty of good roughage.[22] However, even in mature horses, serious bone injury may be caused by continued feeding of a ration that is unusually low in these minerals. This was shown in South Dakota experiments in which horses were wintered on straw alone.[23] In California studies, a decided deficiency of calcium and phosphorus in the rations of stallions seemed to cause a marked decrease in the quality of their semen.[24]

Growing colts must have an ample supply of calcium and phosphorus and also sufficient vitamin D to enable them to develop strong, sound bones. Likewise, pregnant mares and mares nursing foals require much more calcium and phosphorus than do other mature horses. Well-cured legume hay or mixed hay high in legumes is the best roughage for colts and brood mares during the winter season.

A bone disease often called "big head" may be caused in horses, donkeys, and mules by rations very low in calcium, especially when there is an excess of phosphorus.[25] (152) In this disease there is swelling of the jaws and later some of the bones of the head become greatly enlarged. The bones also become porous and frequent fractures occur. Young horses are affected more often than old ones.

In areas where there is a deficiency of iodine, brood mares should be fed iodized salt during at least the latter half of pregnancy, to avoid danger of goiter in the new-born foals. It is the belief of some that navel-ill and trouble from weakness of foals at birth may be lessened by feeding brood mares during pregnancy 14 to 15 grains of potassium iodide per head a week, with their grain.[26]

1351. Salt.—Horses should be supplied regularly with salt. An allowance of 1.75 to 2.00 ounces per head daily is sufficient, and many horses eat less.[27] A good plan is to supply salt where they can take what they wish, either loose salt from a suitable box, or block salt. Horses at hard work need more salt than others, for considerable is excreted in the sweat.

1352. Requirements for vitamins.—There are commonly no deficiencies of vitamins for mature work horses in ordinary rations that contain plenty of good hay, for their vitamin requirements are small. The vitamin needs of brood mares and colts are higher, but they will be amply met if good legume or mixed hay is fed when the horses are not on pasture.

California investigations indicate that the requirements of horses for vitamin A or carotene per unit of body weight are about the same as those for cattle, sheep, or swine.[28] In these studies a deficiency of vitamin A caused night blindness, eye injury, respiratory and reproductive difficulties, and eventually death.

Colts sometimes develop rickets, because of a lack of vitamin D or of calcium and phosphorus. This rarely happens when they have enough well-cured hay. If a colt shows any symptoms of rickets, it should be given an ounce of cod-liver oil a day, or an equivalent amount of a vitamin D concentrate. Also,

a mineral mixture should be supplied, as recommended in Chapter VI. (185)

Differing from ruminants, horses require certain vitamin B-complex vitamins in their feed. This is apparently because there is less synthesis of these vitamins in the digestive tract than in the case of cattle or sheep. (208) However, the usual rations fed horses, containing plenty of good hay, will ordinarily provide enough of the B-complex vitamins.

In a Kentucky experiment there was no benefit from adding a B-complex vitamin supplement to the usual ration fed young Thoroughbred pregnant mares.[29]

In Texas studies an artificial ration purposely made deficient in B-complex vitamins failed to produce normal growth of ponies.[30] When 10 per cent of yeast was added to provide the B-complex vitamins, the growth was satisfactory, and nearly as good gains were made when the ration was supplemented with riboflavin and pantothenic acid.

It has been reported that moon blindness, or periodic ophthalmia, in horses can be prevented but not cured by adding 40 milligrams of riboflavin per head daily to the rations of horses.[31]

1353. Watering horses.—Plenty of water of good quality is essential for horses. About 10 to 12 gallons, or 80 to 100 lbs., of water should be provided daily for each horse. In warm weather and when at hard work, horses will drink more water than at other times, owing to the greater evaporation of water from the body. They also drink more water when fed legume hay than when the roughage is grass hay.

Horses may be watered before, after, or during a meal without interfering with the digestion or absorption of food.[32] However, they should be watered at regular times. A horse that has been worked hard should be watered before being fed, but he should not be allowed much water when very warm. A moderate drink taken slowly will refresh him and do no harm.

During hot weather horses should be watered every hour or two while at hard work, for they need a frequent drink of water nearly as much as does a man under similar conditions. Taking a can or barrel of water along to the field, so the horses can be thus watered, aids greatly in preventing injury from overheating.

III. Preparation of Feed; General Problems

1354. Grinding or crushing grain; soaking feed.—For horses whose teeth are in good condition, there is no need to grind or crush corn or oats. Corn is best fed on the cob or as shelled corn. (701) Ear corn that is very hard and flinty should be ground or soaked.

Grinding oats for work horses increases the value only about 5 per cent. (724) In Michigan trials crushing a mixture of half shelled corn and half oats did not increase its value enough to justify the expense of preparation.[33] For foals up to at least 7 or 8 months of age, grinding or crushing oats is advisable.[34]

Barley, wheat, rye, and the grain sorghums should be ground or crushed for horses, because the kernels are so small that the grain is chewed less thoroughly than corn or oats. If these smaller grains cannot conveniently be ground or crushed, they should be soaked before feeding, to soften the kernels.

There is no advantage in cooking, fermenting, or predigesting feed for horses. (94–95)

1355. Chopping or grinding hay or other roughage.—Experiments have shown that chopping or cutting good-quality hay for horses does not increase its value enough to warrant the expense.[35] If the hay is of poor quality, chopping it may reduce the wastage sufficiently to be worth while. Grinding hay is not advisable for horses, as the ground hay is dusty and may irritate the nasal passages.

It generally pays to chop or shred corn or sorghum fodder or stover in order to lessen the waste. In some regions of Europe a common practice is to mix chopped straw with chopped hay, more straw thus being eaten than would be consumed otherwise.

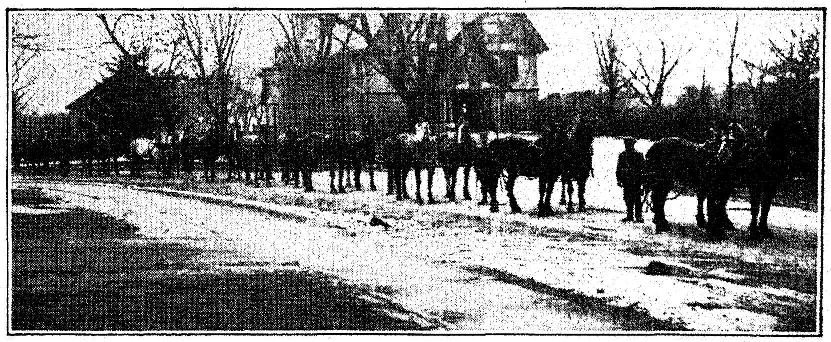
1356. Self-feeding.—The self-feeding method, which is so successful with pigs and is also used for fattening cattle and sheep, is not satisfactory for horses. Even if a mixture of cut hay and grain is fed, it is impossible to adjust the amounts of grain for the various horses so that the easy keepers are not overfed and the hard keepers underfed.

Mules can, however, be satisfactorily self-fed grain or a mixture of grain and protein supplement, with hay fed separately in a rack. Also, a mixture of grain and chopped or ground hay can be self-fed as the entire ration. When mules were self-fed grain in Mississippi tests, they did not gorge on it, as horses would have done, and there was no trouble from digestive disturbances.[36] However, they ate more grain and less hay than hand-fed mules, and the feed cost was 19 per cent higher.

1357. Hints on caring for horses.—Horses must have regular exercise for health and a long period of usefulness. Plenty of exercise is especially important for brood mares, stallions, and colts. When idle, work horses should be turned out where they can exercise.

To keep them in good health, horses should be housed in well-ventilated quarters and be protected from drafts. Cool quarters with good ventilation are far preferable to warm, close stables. The stalls should be well bedded, so the horses will be comfortable at night.

Thorough and careful grooming is necessary to remove the waste material left on a horse's coat when the sweat evaporates, and to keep the pores open and the skin healthy. As idle horses running at pasture sweat little and have abundant opportunity to roll, grooming them is unnecessary. While grooming should be thorough, a dull currycomb is preferable to a sharp one, and a brush should be used on the tender head and legs.



FARM HORSES USED IN WISCONSIN FEEDING TRIALS

Experiments during two years by the author and associates with these horses proved that crushing oats makes a saving of only about 5 per cent.

A good horseman always cares for the teeth of his horses and sees that no sharp points prevent proper chewing of the food. He also sees that the collar and harness fit well and that the horses' feet are properly cared for. He wipes collars and collar pads clean with a damp cloth each evening and allows them to dry before being used again. At the close of the day's work, especially at the start of the season, he takes time to wash the shoulders of the horses with a strong salt solution, as he knows this will help prevent sore shoulders.

A good horseman makes changes in the ration gradually, for a sudden change may cause colic. In starting the day's work he gradually warms the horses to their task before they are put to extreme exertion. In cold weather he blankets his

horses whenever the work ceases and they are forced to stand in the cold even a short time.

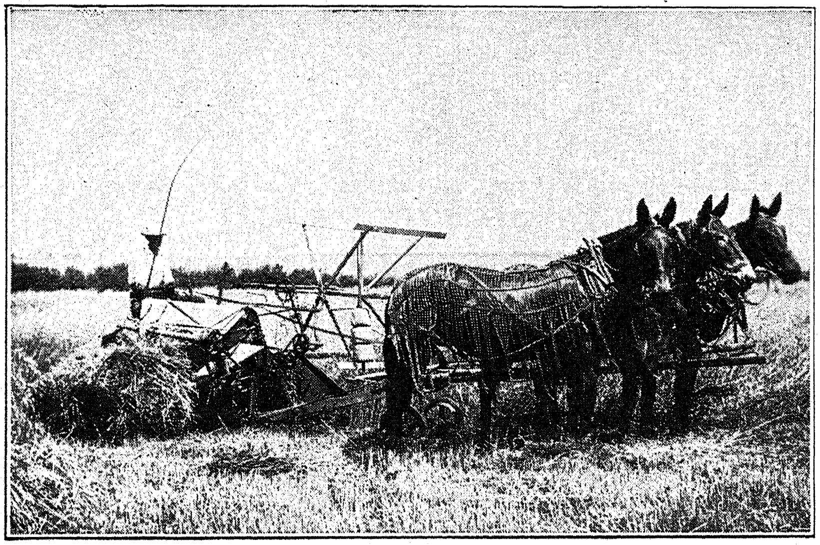
1358. Mules.—Mules are more hardy than horses and are able to give satisfactory service under adverse conditions. Also, they may require slightly less feed than horses to do a given amount of work.

Mules are generally more sensible in eating and less likely to gorge themselves than horses, and hence are less subject to colic. Indeed, mules are often fed at troughs, like cattle, and allowed to eat all they desire. They are not fastidious in their taste and will consume roughages that horses would refuse. Mules also endure hot weather better, and because of the peculiar shape of the foot and its thick, strong wall and sole, they are less subject than horses to foot lameness. These good qualities of mules are partly offset by their stubbornness and other peculiarities of disposition.

Though mules will endure more neglect than horses, good care and feed will prove profitable. For feeding mules the same feeds may be used as in the case of horses, and the same principles apply in suiting the amount of feed to the size of the animal and the severity of the work performed.

QUESTIONS

1. Define *horse power.* How heavy a horse does it take to perform 1.0 horse power of work at steady labor?
2. What factors determine the amount of work a horse can do?
3. State the various types of work that horses perform.



MULES ON A CORN-BELT FARM

Mules are the chief work animals on southern farms and are often used in the corn belt.

4. Discuss the influence of speed upon the efficiency with which horses perform work; the influence of grade.
5. What is the relative efficiency of large and small horses in doing work?
6. Discuss the efficiency of the horse as a motor.
7. Compare the digestibility of feeds by horses and by ruminants.
8. Should horses be allowed to eat all the good-quality hay they will consume?
9. Approximately what is the relative value per pound of grain and hay for the production of work?
10. Discuss the nutrient requirements of horses under the following headings:

(a) Protein; (b) salt; (c) other minerals; (d) vitamins; (e) water.

11. Are the following methods of preparing feed for horses advisable; (a) Grinding corn; (b) grinding or crushing oats; (c) grinding barley, wheat, or grain sorghum; (d) chopping hay; (e) grinding hay?
12. Discuss the use of self-feeders in feeding horses and in feeding mules.
13. Mention some important points to be observed in caring for horses.
14. What advantages and disadvantages do mules have in comparison with horses?

REFERENCES

1. Ritzman, N.H. Buls. 262, 270.
2. Collins and Caine, Iowa Bul. 240.
3. Edmonds, Robbins, and Crawford, Ill. Rpts. 1928, 1929; Crawford, Robbins, and Dawson, Ill. Rpt. 1933; Collins and Caine, Iowa Bul. 240; Rhoad, N.Y., Amer. Soc. Anim. Prod., Proc. 1928; Phillips, Madsen, and Smith, Utah Cir. 114.
4. Agg, Construction of Roads and Pavements, p. 343; Collins and Caine, Iowa Bul. 240; Wooley and Jones. Mo. Bul. 237.
5. Zuntz, Germany, Landw. Jahrb., 27, 1898, Sup. III.
6. Hall and Brody, Mo. Res. Bul. 208; Proctor, Brody, Jones and Chittenden, Mo. Res. Bul. 209; Brody, Bioenergetics and Growth, 1945.
7. Ritzman, N.H. Buls. 319, 330; Ritzman and Colovos, N.H. Bul. 345.
8. Proctor, Brody, Jones, and Chittenden, Mo. Res. Bul. 209.
9. Brody, Bioenergetics and Growth, pp. 898–918; Brody and Cunningham, Mo. Res. Bul. 244.
10. Brackett et al, Nebr. Bul. 277.
11. Ritzman, N.H. Bul. 262.
12. Lindsey and Archibald, Mass. Bul. 230; Armsby, The Nutrition of Farm Animals, pp. 604–606.
13. Grandeau and Le Clerc, Ann. Sci. Agron., 1884, II, p. 235; Colin, Traite Physiol. Comp. Anim., 1886, p. 822; Tangl, Pflüger's Arch. Physiol., 63, 1896, p. 545; Scheunert, Pflüger's Arch. Physiol., 109, 1905, pp. 145–198.
14. Simms and Williams, Conn. (Storrs) Bul. 173; see also: Harvey, Minn., Amer. Soc. Anim. Prod., Proc. 1934.
15. Pearson, Sheybani, and Schmidt, Texas, Jour. Anim. Sci., 3, 1944, pp. 166–174.
16. Earle, U.S.D.A., Jour. Anim. Sci., 9, 1950, pp. 255–260.
17. Simms and Williams, Conn. (Storrs) Buls. 132, 173; Clark, Mont. Bul. 95.
18. Zuntz, Landw. Jahrb., 27, 1898, Sup. III; Armsby, Nutrition of Farm Animals; Harper, N.Y. (Cornell) Bul. 437; N.Y. (Cornell) Rpt. 1930; Simms and Williams, Conn. (Storrs) Bul. 173; Hansson, Meddel. Centralanst. Försöksv. Jordbruk. (Sweden), No. 253, 1924.
19. Thomas and Culbertson, Iowa Rpts. 1940, Part I; 1942, Part I; Harvey, Thomas, Culbertson, and Collins, Iowa, Amer. Soc. Anim. Prod., Proc. 1939; Grandeau and Le Clerc, Ann. Sci. Agron., 1901, II, p. 38.
20. Harper, N.Y. (Cornell) Rpts. 1933, 1934, 1936.
21. Harvey, Thomas, Culbertson, and Collins, Iowa, Jour. Anim. Sci., 2, 1943, pp. 103–111.
22. Caine, Iowa Cir. 130, Iowa Rpt. 1929; Harper and Watt, N.Y. (Cornell) Rpt. 1936.
23. Dunbar, S.D. Bul. 212; see also: Scheunert, Schattke, and Weise, Biochem. Ztschr., 139, 1923, pp. 1–9; Bang, K. Vet. og. Land., Denmark, Aarsskr. 1925; Niimi, Aoki, and Kato, Jour. Japan Soc. Vet. Sci., 6, 1927, Nos. 3, 4; 7, 1928, No. 3.
24. Cal. Rpt. 1926.
25. Kintner and Holt, Philippine Jour. Sci., 49, 1932, pp. 1–89; Sumulong, Philippine Jour. Anim. Sci., 53, 1934, pp. 141–158.
26. Rodenwold and Simms, Amer. Soc. Anim. Prod., Proc. 1934; Harvey, Amer. Soc. Anim. Prod., Proc. 1929; Ore. Bul. 359.
27. Hudson, Mich. Quar. Bul., 8, 1926, No. 3; Templeton, Miss. Rpt. 1928.
28. Howell, Hart, and Ittner, Cal., Amer. Vet. Res. Jour., 2, 1941, pp. 60–74; Hart, Goss and Guilbert, Cal., Amer. Vet. Res. Jour., 4, 1943, pp. 162–168; Cal. Rpt. 1938–40.
29. Ky. Rpt. 1950.
30. Pearson, Sheybani, and Schmidt, Texas, Jour. Anim. Sci., 7, 1948, pp. 78–83; see also: Carroll, Cal., Jour. Anim. Sci., 9, 1950, pp. 139–142.
31. Jones, Roby, and Mauer, Amer. Jour. Vet. Res., 7, 1946, pp. 403–406; Jones, Jour. Amer. Vet. Med. Assoc., 114, 1949, pp. 326–329.
32. Tangl., Landw. Vers. Stat., 57, 1902, p. 329.
33. Hudson, Mich. Quar. Bul., 16, 1933, No. 1.
34. Caine, Iowa Bul. 347.
35. Caine, Iowa Bul. 347; Kuykendall, Miss. Bul. 305; Harper, N.Y. (Cornell) Bul. 437; Morrison, Fuller, Arneson, and Roche, Wis. Buls. 388, 396; Roche, Fuller, and Bohstedt, Wis. Res. Bul. 102.
36. Templeton, Miss. Bul. 270.

CHAPTER XXXIII

FEEDING AND CARING FOR HORSES

I. Feeding Work Horses

1359. Many feeds suitable for horses and mules.—In most localities the usual ration for horses and mules consists of only one or two kinds of grain, with no more variety in the roughages. Over much of the United States oats are the grain most commonly fed to horses, and some horsemen consider them indispensable. However, entirely satisfactory results are secured with grain mixtures that contain no oats, but which are balanced in nutrients and have the proper bulkiness.

Many experiments have shown that in making up rations for horses, just as for other stock, the prices of the different available feeds should always be considered. A ration should be selected that will be as cheap as possible, yet entirely satisfactory for keeping the animals thrifty and efficient over a long period of usefulness.

It is more important for horses than for other stock that the feeds be of sound quality and not moldy, spoiled, or extremely dusty. This is because horses are especially apt to be injured by damaged feeds, and dusty hay or fodder greatly increases the trouble from heaves.

The composition and value of the many feeds that may be fed to horses and mules are discussed in the various chapters of Part II.

The experiments conducted to study problems in feeding and caring for work stock have nearly all been with horses, and few have been with mules. Therefore most of the discussions in this chapter deal with horses. However, the same general principles apply in feeding and caring for mules as in the case of horses.

The discussions in this chapter deal chiefly with the feeding and care of draft horses. However, brief summaries are given later concerning the special requirements of saddle horses and other light horses, including race horses.

1360. Grains and other concentrates for horses and mules.—Because of their bulky nature, oats are the safest of all common grains for horses and mules, as has been emphasized in Chapter XX.

However, corn, barley, wheat, and the grain sorghums can all be used successfully in place of oats, when fed as advised in the chapters in which these grains are discussed. Ground or crushed rye should not form more than one-third of the concentrate mixture. Hominy feed is a satisfactory substitute for oats, and molasses is sometimes fed to horses as an appetizer or conditioner, or as a grain substitute when cheap in price.

Among the protein supplements, wheat bran is especially useful because of its bulky nature and its laxative effect. Linseed meal is deservedly popular on account of its laxative and conditioning effect. Other protein supplements, such as soybean oil meal, cottonseed meal, and corn gluten feed, can be used for feeding horses and mules, as has been stated in the chapters of Part II.

1361. Hay and other roughages for horses and mules.—In the northern states timothy hay is the standard roughage for horses and mules, and in the South hay from other grasses, such as Bermuda grass, Johnson grass, or Dallis grass. One of the reasons for the popularity of grass hay for horses and mules is that it is usually free from mold or dust. Also, grass hay much more nearly approaches legume hay in actual nutritive value for feeding work horses or mature light horses than it does for other classes of stock. This is because of the low requirements of such horses for protein, minerals, and vitamins. (**1345**)

Well-cured legume hay or mixed

legume-and-grass hay is entirely satisfactory for horses and mules, if it is properly fed. The common prejudice against legume hay for horse feeding is due to the use of poor-quality hay or to feeding an excessive amount. Horses are so fond of good legume hay that they are apt to eat too much for their own good, if such hay is fed too liberally. They should therefore be fed no more than they need. Since good legume hay is higher in digestible nutrients than most grass hay, less of it is needed to replace a given amount of grass hay.

TIMOTHY POPULAR FOR HORSES

Timothy hay and other grass hays are the standard roughages for horses and mules.

It is important that legume or mixed hay for horses be bright and well cured, for that which is moldy or dusty may cause heaves. Dampening dusty hay before feeding helps somewhat, but it is far better to prevent mold and dust by proper curing.

Well-cured corn or sorghum fodder or stover can be substituted for hay in feeding horses and mules, especially those that are idle or at light work. Straw can also be used as a considerable part of the roughage for wintering idle work stock. If better roughage is scarce, some straw can even be used for work horses in place of hay. In such a case, it had best be chopped and mixed with the concentrates.

Silage of good quality, free from decay or mold, may replace one-third to one-half the hay usually fed to horses and mules. Poor quality silage should never be fed to horses, for they are much more susceptible to injury from spoiled silage than are other stock. Horses and mules should be accustomed to silage gradually. Because of its bulky nature, horses at hard work should not be fed much silage, but it is well suited for idle horses, brood mares, and growing colts.

1362. Pasture.—Through the well-planned use of pasture, the cost of keeping farm work horses and mules can usually be decidedly reduced. Good pasture is even more important for colts and brood mares.

Whenever farm work animals are idle during the pasture season, they should be turned to pasture, thus reducing the labor and expense to a minimum. Even when horses are worked regularly, it is best to turn them out at night, after they have eaten their grain, into a near-by pasture which has been fertilized so that there is plenty of grass. This not only reduces the cost of feed but also helps to keep them thrifty. During hot weather, horses are much more comfortable at night when turned out to pasture than when kept in the stable.

The saving in feed that can be made by such use of pasture is shown by Mississippi experiments.[1] In a 3-year test, work mules which had access to good pasture at night and on idle days during the grazing season needed about 25 per cent less grain and 50 per cent less hay than their teammates which had no pasture. The mules having pasture also gained 50 lbs. more per head and were as efficient workers as those not pastured.

Work stock should not be turned on pasture too early in the spring, as the grass is then too laxative. Also, it is best to accustom them to pasture gradually, and the pasturing should be regular, and not intermittent. When work horses are pastured, the other feeds should not be of a laxative nature.

After the harvest is over in the fall, horses not needed for work should be turned to pasture. They should have

access to a shed and some good-quality dry roughage should be fed in a rack, to supplement such feed as they can secure from stalk and stubble fields and from meadows. Where there is little snow in winter, idle horses can get no small part of their winter feed by cleaning up such fields.

Colts and also brood mares which are not at work should be on good pasture throughout the growing season, care being taken that they actually have enough feed to keep them thrifty. City horses are often turned on pasture so that their feet may recover from the ill effects of hard pavements.

For early spring and for fall pasture, bluegrass or other permanent pasture is excellent. Mixed pasture that contains considerable white clover or other legumes is even better than grass alone.

The use of pastures grown in the regular crop rotation, instead of parasite-infested permanent pasture, will help greatly to reduce trouble from internal parasites. Since horses are much less subject to bloat than are cattle or sheep, alfalfa and other legume pasture is excellent for them. Such mixtures as alfalfa and bromegrass furnish ideal pasture.

1363. Feeding work horses.—As a guide in selecting economical rations for work horses, several example rations are given in Appendix Table VII for 1,200-pound horses which are at hard, medium, and light work and for horses which are idle. All these rations meet the requirements according to the Morrison feeding standards and should prove satisfactory in practice. With horses of other weights, the rations should be increased or decreased by approximately one-twelfth the amounts of feed shown, for each 100 lbs. the live weight differs from 1,200 lbs. A horse that is a hard keeper will need considerably more grain than an easy keeper doing the same amount of work.

Usually the daily amount of grain or other concentrates is divided equally into 3 feeds, and given at morning, noon, and night. It is best to feed only a small amount of hay in the morning, so the horse's digestive tract will not be too much distended when he is at work. A common plan is to feed about one-fourth the daily allowance of hay in the morning, one-fourth at noon, and one-half at night. Some omit the noon feeding and give one-third the hay in the morning and the remainder at night, when the horses have plenty of time to eat it.

Horses that are inclined to bolt their grain, or eat it too rapidly, can be made to eat more slowly by placing in the feed box several smooth stones about 3 inches in diameter, or a few whole corn cobs. Another method is to feed the grain well spread out in a large, flat feed box, or else to mix it with bran or chopped hay.

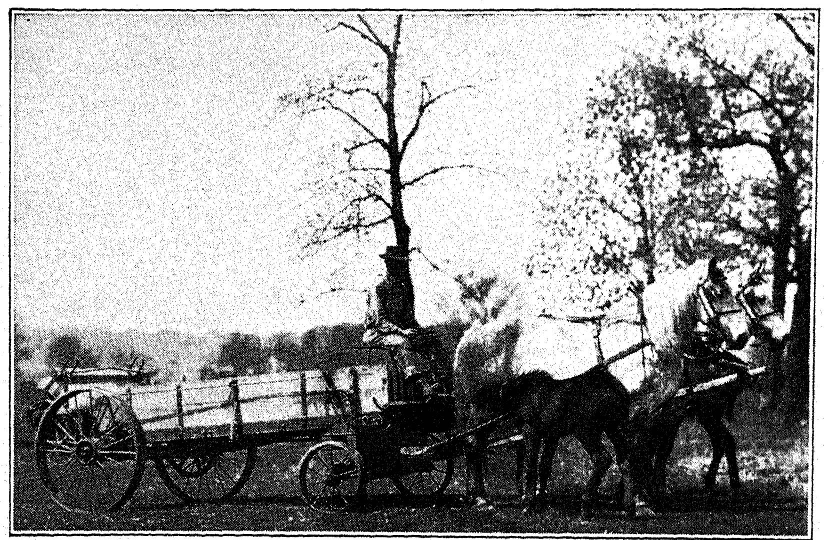
To avoid digestive troubles and possible deaths from azoturia, the allowance of grain for horses at hard work should be reduced on idle days to 50 to 70 per cent of the amount usually fed. It is best to feed on such days in place of the grain, a mixture of two-thirds grain and one-third bran. Some feed a small allowance of grain at noon on idle days, with only a bran mash both morning and night.

On coming to the stable at noon, the work horse should have a drink of fresh water, care being taken, if he is warm, that he does not drink too rapidly, or too much. Before going to work, he should be watered again. If possible, an hour should be allowed for the mid-day meal, and some horsemen remove the harness so the horse can eat his meal in comfort and rest easily. When the horse comes in after the day's labor, he should be given a drink, unharnessed at once, and when the sweat has dried, brushed well. Horses will also appreciate a drink in the evening after they have eaten most of their hay.

1364. Wintering farm horses.—When farm horses are idle during the winter, they should be maintained largely on cheap roughage. Idle horses can get much of their feed in fall and early winter by grazing the aftermath in meadows or by cleaning up stalk and stubble fields. Often they can be fed the refuse stems from clover or alfalfa hay which

has been fed to other stock. Straw or stover from corn or the sorghums can also form a considerable part of their ration, but care should be taken to supply some feeds higher in protein, minerals, and vitamins, or bad results may follow. If not provided more liberally, it is wise to feed 5 lbs. per head of legume hay at least 3 times a week. Light grain feeding should begin a few weeks before spring work starts, to get the horses into condition for work.

Idle horses should be turned out daily in winter for exercise in a lot that is protected from the wind. If they have the run of fields during the winter, they should have access to a dry shed for shelter, except where the weather is mild.



A Good Team of Brood Mares

Such mares can do farm work most of the year and also raise good colts.

II. Raising Horses; Feed Requirements

1365. Feed and care of brood mares.—It does not take very much more feed to keep a brood mare throughout the year than it does to feed another horse doing an equal amount of work.

Good results cannot be secured, however, unless a brood mare has proper feed and care. It is estimated that only 60 per cent of the brood mares that are bred each year produce living foals. This enormous loss is largely due to neglect and carelessness.

Idleness must be avoided in the case of brood mares. The best exercise is regular work, yet judgment must always be used in working brood mares. Pulling too hard, backing heavy loads, wading through deep snow or mud, or other over-exertion is dangerous. When not worked, a mare should be turned out daily for exercise. As foaling time approaches, the work should be lightened, and preferably discontinued 3 days to a week before foaling. When laid off, the mare should still be allowed to exercise. Mares heavy in foal are apt to be cross and quarrelsome, but they should always be handled gently.

The rations for brood mares should contain liberal amounts of protein, calcium, phosphorus, and vitamins. An abundance of these nutrients is especially needed by mares that are suckling foals and by young mares that are still growing. Several example rations for mares suckling foals are given in Appendix Table VII.

To supply sufficient protein, min-

erals, and vitamins, it is desirable that at least half the roughage for brood mares during the winter be legume hay. The rest may be grass hay, corn stover, corn silage, or even good straw. Brood mares which are idle during the winter need but little concentrates, if they have plenty of good roughage. Sufficient grain or other concentrates should be fed, if needed, to keep the mares in thrifty condition, but they should not become fat. Constipation should be prevented by using such feeds as bran or linseed meal.

1366. Gestation period and foaling time.—The average gestation period for mares is about 11 months, or 335 days, though it may vary considerably. In California studies the gestation period of Arabian mares bred from December through May averaged 10 days longer than of mares bred the rest of the year.[2]

Shortly before foaling, the grain allowance should be decreased and enough bran or other laxative feeds used so that the mare will not be constipated. Unless the mare can foal on pasture, a roomy box stall should be provided, which has been thoroughly cleaned and disinfected to avoid infection that may cause navel ill and joint disease. The stall should be kept well cleaned and should be bedded with dry straw. If the mare has difficulty in foaling, a veterinarian should be secured.

The mare should be given a half bucket of lukewarm water before foaling, and when on her feet again she will need another drink. A light feed of bran is suitable for the first meal, and this may be followed by oats, or by such a mixture as oats and bran. After foaling, the mare should be confined for a few days, her ration not being too abundant. If all goes well, after 4 or 5 days she may be turned to pasture, and in 10 days, if work is urgent and the mare has fully recovered, she may go back to light work, for a part of the day at least.

Farm mares should not usually be bred until they are 3 years old. Breeding a well-grown draft filly at 2 years will, however, not be noticeably detrimental to her, if she is well fed and cared for.

1367. The foal.—To reach good size at maturity, a foal should make about half its entire growth during the first year. It should therefore be fed liberally, so that its growth will not be checked at any time. Soon after birth, the foal should get the colostrum, or first milk, of its dam, because this increases the resistance of the digestive tract to bacterial infection. If the foal is constipated, a dose of castor oil or a rectal injection may be necessary. On account of the great danger from navel and joint disease, the stump of the navel cord should be carefully disinfected.

If the dam does not supply enough milk, she should receive feed that will stimulate her milk flow. Good pasture is best, but if this is not available, she should have a liberal amount of grain. On the other hand, an oversupply of milk or milk too rich in fat may cause indigestion in the foal. The dam's ration should then be reduced and some of her milk drawn, the foal being allowed the first portion, which is the poorest in fat.

1368. Mare's milk.—Mare's milk is white or bluish in color with an aromatic, sweetish, slightly bitter taste. As is shown in Appendix Table I, it is much lower in fat, protein, and mineral matter than is cow's milk, but it is somewhat richer in milk sugar. The milk yield of good brood mares is greater than is often supposed. In German tests the daily milk yield of draft brood mares suckling foals was 26 to 77 lbs.[3]

1369. Raising the orphan foal.—If a mare dies, the foal may, with proper care, be raised on cow's milk. In case the foal has not secured colostrum from its dam, it will be necessary for the veterinarian to provide a substitute by the hypodermic injection of horse serum, or by other means.[4] **(270)**

As mare's milk contains much less fat but more sugar than cow's milk, the milk should be modified for a very young foal. Choose a cow in the first part of the lactation period and one giving milk low in fat, if possible. To 1 pint of milk add one-fourth pint of limewater and 1 teaspoonful of sugar. This will be enough for 2 feedings at first. Feed the foal about every hour for the first day or so, warming the milk to 100° F. and using an ordinary nursing bottle with a large nipple. This must be carefully cleansed and sterilized.

If the foal is doing well, the amount of milk may be gradually increased and the period between feedings lengthened, until the foal is fed only 4 times a day. After a few

days unmodified whole milk may be substituted and the foal taught to drink from a pail. In 5 to 6 weeks sweet skimmilk may gradually replace the whole milk and after 3 months the foal may be given all it will drink 3 times a day. As soon as possible, the foal should be fed solid food, such as crushed or ground oats, bran, a little linseed meal, and legume hay. It should also have the run of a paddock where there is good grazing.

1370. Weights and gains of colts.—At the Iowa Station the average birth weight of Percheron and Belgian colts for 4 years was 159 lbs.[5] At a year of age these liberally-fed colts averaged 1,105 lbs.; at 2 years of age, 1,506 lbs.; and at 3 years of age, 1,619 lbs.

At Macdonald College, Canada, draft colts weighed somewhat less at birth, averaging 120 lbs.[6] Their average weights at various ages were as follows: 6 months old, 730 lbs.; 1 year, 1,020 lbs.; 18 months, 1,350 lbs.; 2 years, 1,480 lbs.; 3 years, 1,790 lbs.; and 4 years, 1,980 lbs. During the first 6 months the colts gained an average of 3.4 lbs. a day; from 6 months of age to a year of age, 1.6 lbs. a day; from a year of age to 18 months of age, 1.8 lbs. a day; during the next 6 months, 0.7 lb. a day; during the third year, 0.9 lb. a day; and during the fourth year, 0.5 lb. a day.

Allen found that 1,071 trotting-bred foals averaged 110 lbs. at birth.[7] Their average gain was 534 lbs. for the first year, 264 lbs. for the second, 118 lbs. for the third, and 76 lbs. for the fourth, making their average weight 1,102 lbs. at 4 years of age.

Hooper found that Thoroughbred fillies which were foaled from the latter part of February to the end of April averaged 760 lbs. in weight and 14 hands 2 inches in height on April 1 of the next year.[8] Colts averaged 780 lbs. at the same age.

1371. Feeding the foals.—Foals should learn to eat grain as early as possible, so that they will grow rapidly. Also, if the mares are working, the foals will fret less for them. If the feed box is placed low, a foal will begin nibbling from the mother's supply at 3 or 4 weeks of age.

Crushed or ground oats and wheat bran are excellent feeds for young foals, and also such a mixture as 4 parts by weight of ground corn, 3 of bran, and 1 of linseed meal. By the time they are to be weaned, foals should be eating 2 to 3 lbs. of concentrates a day. They should also be given good legume hay as soon as they will eat it, and they should have access to a supply of good water.

If the dam has insufficient milk, the foal may be fed cow's milk, preferably milk low in fat. Constipation may be relieved by adding linseed meal to the ration. If a foal has diarrhea, the feed for both dam and foal should at once be lessened.

If the mares and foals are on pasture, a small enclosure, called a "creep," should be made at a spot where the horses are inclined to loiter, with a gate and also an opening of such size that the foals can enter, while the mares are kept out. Here a suitable grain mixture should be supplied in a feed trough. To accustom the foals to eating in the creep, the gate should be left open for a few days, so the mares can enter and eat the grain mixture. After the mares are shut out, a salt block or a large lump of rock salt can be kept nearby, so the mares will loiter near the creep.

When the mares are worked, it is usually best not to have the foals follow them. A small pasture paddock should be provided for the foals, with a shed for shelter. Burlap sacks hung from such a shed will brush flies off the foals as they pass under them. The mare should be brought to suckle the foal in the middle of the forenoon and afternoon for the first 2 or 3 weeks. Before turning her with the foal, she should be allowed to cool off, and perhaps some of the milk drawn from her udder. If the foal is housed in the barn during the day, it is well to turn both dam and foal to pasture at night. Brood mares at work should be fed a liberal amount of concentrates, so they will keep up a good milk flow.

1372. Weaning.—At from 4 to 6 months of age, the foal should be weaned. When the mare is bred soon after foaling, or if for any reason the dam or foal is not doing well, it is best to wean comparatively early. On the other hand, if the mother has a good flow of milk and her services are not needed, the foal may be allowed to suckle for

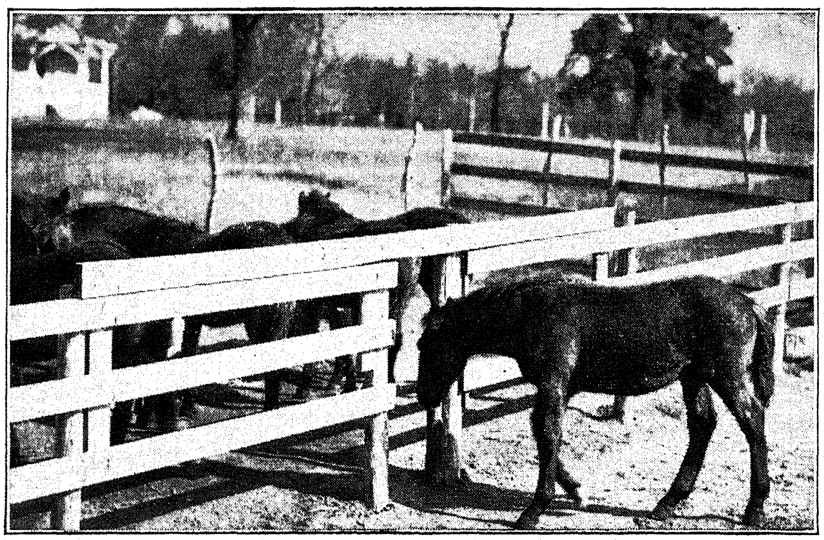
6 months. If the foal is accustomed to eating grain, weaning will cause little, if any, setback.

To wean the foal, it should be separated from its dam and not allowed with her again until they have forgotten each other. The grain allowance of the mare should be reduced till she is dried off, and her udder partly milked out when necessary.

The education of the colt should not be postponed until it is time to "break" him for work. The breaking process will be much easier and the colt will usually make a better-behaved horse if the training starts early. When still a foal, he should be taught to lead at the halter, stand tied in the stall, and display proper stable manners. Well-grown colts may be broken when 2 years old and used for limited work, thus reducing the cost of raising them considerably.

1373. After weaning.—Foals should be kept growing thriftily after weaning, by giving them a liberal amount of feed that supplies plenty of protein and also sufficient vitamins and minerals, especially calcium and phosphorus.

During the pasture season foals should have first-class pasture. Legume pasture or mixed legume-and-grass pasture is excellent. Well-fertilized pasture not only produces more rapid gains than poorer pasture, because of the more abundant feed, but it also tends to develop better bone. In a Georgia test, mule colts pastured on rather poor land which had been fertilized with calcium and phosphorus grew more rapidly and had better bone development than others on unfertilized pasture, even though the latter pasture provided plenty of forage.[9]



A CREEP FOR FEEDING FOALS ON A PASTURE

For foals on pasture with their dams, a creep should be provided, such as this, where the foals can have access to a separate supply of grain or other concentrates.

For roughage during the winter, well-cured legume hay or mixed legume-and-grass hay is the best. If the amount of such hay is limited, at least one feed of it should be provided daily, if possible. The rest of the roughage can be hay from the grasses, well-cured corn or sorghum fodder, or silage from corn or the sorghums.

With good legume hay for roughage, excellent results will be secured with oats as the only concentrate for colts, or from such mixtures as the following:

(1) Equal parts by weight of oats and either corn or barley; (2) a mixture of 3 or 4 parts oats by weight and 1 part wheat bran; (3) a mixture of 3 parts corn and 1 part wheat bran; (4) a mixture of 2 parts corn, 2 parts oats, and 1 part wheat bran.

When the roughage is chiefly grass hay or other low-protein forage, a concentrate mixture higher in protein should be used, such as one of the following: (1) A mixture of 3 parts oats by weight, 3 parts corn, 3 parts bran, and 1 part linseed meal or other protein-rich supplement; or, (2) a mixture of 3 parts corn, 3 parts bran, and 1 part protein-rich supplement.

Many expert horsemen believe that foals develop better quality of bone when the concentrate mixture is made up largely of oats instead of corn, but corn is satisfactory, if care is taken to supply plenty of protein and minerals in the ration, preferably by feeding legume hay.

In raising colts for farm work horses, the cost should be kept as low as possible by the use of a maximum amount of pasture, hay, and other roughage, and a minimum amount of grain or other concentrates. Colts raised in this manner will not be as heavy at 3 years of age as those fed a liberal amount of grain in winter, but they will be nearly as large at maturity and will be just as good work horses.

In a Michigan experiment draft colts raised from weaning on a very liberal amount of grain with what hay they would eat in winter and good pasture in summer averaged 1,574 lbs. in weight and 63.8 inches in height as 3-year-olds.[10] Other colts fed only one-third as much grain, with straw in abundance and a limited amount of hay in winter and good pasture in summer, weighed 1,347 lbs. as 3-year-olds and were 63.0 inches tall. When the colts in the groups reached maturity, there would have undoubtedly been considerably less difference in their weights.

The first group had received from weaning time to 3 years of age an average of 7,360 lbs. concentrates (nearly all oats and ear corn), 7,960 lbs. hay and 240 lbs. straw, in addition to pasture. The other colts had received an average of only 2,380 lbs. concentrates, with 6,400 lbs. hay, 3,720 lbs. straw, and pasture during the summers.

The cost of feed to 3 years of age was 70 per cent more for the liberally-fed colts than for the others. However, they were sufficiently well grown at 2 years of age so that they could have been put to some work. This might have paid for much of their feed the following year.

To reduce the cost of raising colts still further, in other Michigan trials draft colts were fed no concentrates at all after weaning.[11] They were wintered the first and following winters on hay stacked in a pasture field that had not been grazed the previous summer. They had access to a shed for shelter, but usually preferred the shelter of the hay stacks. On this hay, eaten from the stack, and the dried pasturage in winter and with good pasture in summer, they reached an average weight of 1,504 lbs. at 3 years of age. It was estimated that they had eaten an average of about 13,800 lbs. of hay and dried pasturage in the 3 winters. Colts thus wintered chiefly out of doors developed better feet and legs than those wintered in the barn and turned out for exercise daily.

If it is desired to have draft colts make maximum growth to 3 years of age, they will need 5 to 10 lbs. of concentrates a day during the first winter in addition to plenty of good roughage. During the second summer they will need 3 to 6 lbs. of concentrates a day, and during the second winter 6 to 12 lbs. The third summer they will need no concentrates if the pasture is excellent, but if the pasture is none too good, 4 to 5 lbs. of concentrates per head daily may be needed to keep the colts growing rapidly. The third winter the colts will need about the same amount of concentrates as during the second winter.

1374. Feed and care of the stallion.—Nothing so vital to the well-being of the stallion is so often neglected as

proper exercise. The best exercise is actual work, and even during the breeding season a half day's work each day is beneficial. When real work is impossible, the stallion should be turned out daily into a roomy paddock, or should be exercised on the road for a mile, or preferably considerably more.

The ration of the stallion should consist of first-class, wholesome feeds, supplying ample protein, mineral matter, and vitamins for thrift and vigor. It has been mentioned previously that a lack of calcium and phosphorus in the ration of stallions seems to decrease the quality of the semen. (**1350**) In Mississippi investigations the ration also had a marked effect on sperm production.[12] Even with legume hay (lespedeza) as the roughage, a concentrate mixture of 65 parts oats, 25 parts wheat bran, and 10 parts wheat or corn, plus 1 ounce of calcium supplement per head daily, was found to be decidedly superior to using corn as the only concentrate.

For roughage, well-cured mixed legume and grass hay is unexcelled. Pure legume hay is entirely satisfactory, if it is not dusty and if no more is fed than is actually needed.

The following concentrate mixtures are well suited for use with timothy hay or other non-legume roughage: (1) Oats 4 parts by weight, and wheat bran 1 part; (2) oats 4 parts, corn 6 parts, and wheat bran 3 parts; (3) oats 4 parts, corn 4 parts, and linseed meal 1 part. For mature stallions oats can be used as the only concentrate, even when no legume hay is fed. If a considerable proportion of the roughage fed a stallion is legume hay, a mixture of grain alone is satisfactory, even for young stallions. It may, however, be desirable to include a little wheat bran in the mixture, merely for its laxative effect. Even with legume hay as the only roughage, most horsemen prefer not to include more than one-half corn in the grain mixture for stallions.

The stallion should be fed just enough concentrates to keep him in vigorous, thrifty condition, but he should not be allowed to get fat. During the breeding season he will need as much grain as a horse at hard work, and he should be fed enough to prevent him from running down in flesh.

1375. Cost of keeping farm horses.—The most extensive data on the feed required annually by farm horses are studies for the year 1929, made by the United States Department of Agriculture on 736 corn-belt farms.[13] On these farms horses working an average of 691 hours a year consumed annually the following average amounts of feed per head: Oats, 1,565 lbs.; corn, 1,730 lbs.; other concentrates, 18 lbs.; legume and mixed hay, 2,260 lbs.; non-legume hay, 1,060 lbs.; and straw and stover, 1,640 lbs.; with 4.4 months of grass pasture and 1.7 months of grazing on corn stalk and stubble fields.

The cost of the feed was 81 per cent of the total annual net cost, after allowing credit for the value of the manure and a pro-rata credit for colts produced by a few of the mares. At 1929 prices, the net cost per hour of horse labor was 14 cents.

The ways in which the cost of feed can be kept low have been emphasized previously in this chapter. Idle horses or mules must be wintered economically, largely on cheap feeds, such as straw, corn fodder or stover, or waste feed from stubble fields, stalk fields, and meadow aftermath. The efficient use of good pasture, including night pasture for work animals, will also reduce the cost of horse labor. Improper shoeing or a poorly-fitting collar may reduce the capacity for work just as much as feeding an inadequate ration.

The cost per hour of labor will also depend largely on the number of hours of work actually performed a year. Therefore the work should be so planned as to use draft animals efficiently.

Many horses and mules are badly rundown in condition and even unfit for work as a result of severe infection with internal parasites. Proper treatment with suitable vermifuges will produce a striking improvement in their condition, save much feed, and greatly reduce the trouble from colic. Since there is more danger

to horses in administering doses of a vermifuge than in the case of other stock, the treatment had best be given by a veterinarian.

III. Feed and Care of Light Horses

1376. Feeding and caring for light horses.—Because they are generally not exercised for many hours a day, saddle horses and other light horses kept mainly for pleasure usually need less feed in proportion to their weight than do work horses at hard or medium work. All feeds should be of good quality, and the hay should be free from dust or mold.

A common allowance of hay is 1.0 to 1.1 lbs. daily per 100 lbs. live weight. About 1.0 lb. of oats or other concentrates per 100 lbs. weight should be enough for horses ridden or driven a moderate amount daily. Concentrates are commonly fed 3 times a day, the evening meal being the largest.

Oats are superior to any other single grain or concentrate for light horses.[14] However, a suitable combination of other grain and some bulkier feed gives good results, just as in the case of work horses. In case the horse is at all constipated, bran should be fed, dry or as a mash. On the other hand, light horses should not be fed too large amounts of such laxative feeds as alfalfa or clover hay or bran.

The period of satisfactory service of light horses is often lessened because they are overfed and exercised irregularly or too little. On days when they get little exercise, the usual amount of roughage may be fed but the grain allowance should be reduced, as in the case of work horses. (1363)

The amount of feed needed by saddle horses used on ranches or farms for handling stock will depend on the amount of work they actually perform. During much of the year such horses can get most of their feed from suitable pasture that is close at hand.

1377. Feed and care of race horses.—The same general principles apply to the raising of Thoroughbreds and other race horses as in the case of other horses, except that expense is not spared in providing rations that will insure proper development. The rations and methods differ to a considerable extent on various noted farms where race horses are raised.[15] This shows that there is no one best way of raising such horses. However, there is general agreement in certain practices and methods.

Commonly, excellent pasture is provided for brood mares, stallions, and colts throughout the growing season. In winter, care is taken to insure abundant exercise during the daytime in suitable paddocks or pastures. Because of its higher content of protein, vitamins, and calcium, mixed hay or legume hay of first-rate quality is generally preferred to straight grass hay.

A sufficient amount of concentrates is fed to keep the mares and stallions in the desired condition and to produce rapid growth in the colts. There is considerable difference in the concentrate mixtures used on the various farms. Oats are the most popular grain on Kentucky horse farms and commonly form a large part of the concentrate mixture.

Often cracked corn or shelled corn is included in the mixture and sometimes cracked or rolled barley. Wheat bran and linseed meal are common ingredients, and sometimes a molasses feed is added. Generally, the horses are given access to bone meal or to a mineral mixture furnishing calcium and phosphorus, so they will have a plentiful supply of these bone-building minerals.

Often yearlings that are to be sold in the spring are fed a very liberal amount of concentrates in winter, so they will not only make rapid growth but will also become fat and appear more attractive to purchasers. Opinions have been expressed that this practice may be decidedly detrimental.[16] It is believed that it may tend to produce horses with feet and legs that will not stand the strains of racing so well as when the yearlings are fed for only normal growth.

During the training and racing season, the amount of hay for a race horse must be strictly limited. Often only 7 or 8 lbs. of hay are fed a day.[17] Some horses

must be muzzled to prevent them from eating the bedding.

The allowance of oats or of concentrate mixture will range from 8 to 10 lbs. a day up to 13 lbs. or more. During the training period, a bran mash about once a week helps to keep the horse's bowels in proper condition.

QUESTIONS

1. Discuss the value of grass hay and of legume hay for horses and mules. What kinds of hay are generally fed to them in your region?
2. Why are oats so popular for feeding horses? How can other grains be satisfactorily substituted for oats?
3. Discuss the importance of pasture in reducing the cost of keeping work horses and mules.
4. State some of the most important points in feeding work horses. About how great an amount of concentrates and roughages combined should be fed daily to work horses per 100 lbs. live weight?
5. What sort of rations should be used for wintering idle farm horses?
6. Discuss the feed and care of brood mares: (a) Previous to foaling; (b) at foaling time.
7. Discuss the feed and care of the stallion.
8. Summarize the important points in feeding and caring for foals: (a) Before weaning; (b) at weaning time; (c) after weaning.
9. Approximately how much total concentrates and how much roughage does it take to raise a draft colt to 3 years of age: (a) When it is fed a liberal amount of grain; (b) when only enough grain is fed to produce satisfactory growth?
10. What are the chief items of expense in raising draft horses?
11. How can the cost of horse or mule labor be reduced to a minimum?
12. State a satisfactory ration for a saddle horse or other light horse.

REFERENCES

1. Miss. Rpt. 1940.
2. Howell and Rollins, Cal., Jour. Anim. Sci., 10, 1951, pp. 789–796.
3. Blechschmidt, Germany, Landw. Jahrb., 77, 1933, pp. 463–560.
4. Gamble, Earle, and Howe, U.S.D.A. Tech. Bul. 661.
5. Caine, Iowa Rpt. 1943, Part 1.
6. Crampton. Macdonald College, Canada, information to the author; see also: Fuller, Wis. Cir. 244; Breeder's Gazette, 59, 1911, p. 1223.
7. Allen Farm Catalog, 1905.
8. Hooper, The Thoroughbred Record, July 9, 1921.
9. Edwards, Ga., Amer. Soc. Anim. Prod., Proc. 1940.
10. Hudson, Mich. Spec. Bul. 253; Blakeslee and Brewster, Mich. Quar. Bul., 23, 1941, No. 4; see also: Trowbridge, Chittenden, Moffett, and Elijah, Mo. Buls. 316, 413, 444; Snyder, Nebr. Bul. 130.
11. Hudson and Good, Mich. Quar. Bul., 28, 1946, No. 3.
12. Berliner, Cowart, and Pharis, Miss., Amer. Soc. Anim. Prod., Proc. 1939; Miss., Rpts. 1939, 1941.
13. Reynoldson et al., U.S.D.A. Tech. Bul. 384.
14. Kays, The Horse, 1953.
15. Palmer, Feeding Practices on Kentucky Thoroughbred Farms, published by The Bloodhorse, Lexington, Ky., 1943.
16. Buckner, Good, and Harms, Ky., Amer. Soc. Anim. Prod., Proc. 1938; Horlacher, Ky., Amer. Soc. Anim. Prod., Proc. 1940.
17. Woodruff, The Trotting Horse in America.

CHAPTER XXXIV

GENERAL PROBLEMS IN SWINE HUSBANDRY

I. Economy of Pork Production

1378. Efficiency of pigs as meat producers.—It has been pointed out in Chapter XII that pigs excel all other farm animals in the efficiency with which they convert feed into edible meat. (**351–352**) They require much less feed and less total digestible nutrients for each pound of edible meat produced than do other farm animals.

Pigs yield a higher percentage of dressed carcass than do other meat animals; a larger proportion of the carcass is edible; and pork is richer in energy than other meat, because of a higher content of fat and a slightly lower percentage of water. However, beef and mutton usually furnish a higher percentage of protein than does pork.

Pigs have a greater capacity to consume feed in proportion to their live weights than do calves or lambs. Because of this and also because of greater efficiency in the utilization of food nutrients, they make much more rapid gains in proportion to their live weights. Well-fed pigs make more than twice as great a gain per 100 lbs. live weight from weaning time to market weights as do fattening calves, and three times as much as is made by fattening lambs.

Other advantages of swine, in addition to their efficiency in food production, are that they are very prolific and they do not require expensive buildings. Also, they are especially suited to utilize feed that might otherwise be wasted, such as garbage and garden waste. In countries where the density of population presses most upon the food supply, both swine and poultry often get most of their food from such sources. In contrast, in the United States pork production is most important in the corn belt and other districts where grain is abundant.

1379. Efficiency and rate of gain of pigs of various ages.—The amount of feed required for 100 lbs. gain in weight is lowest for young pigs and steadily increases as they grow older and become fatter. This is due to the factors which have been discussed in detail in Chapter IX. (**265**) First of all, the gain made during the early stages of growth or fattening contains more water and much less fat than when the animal becomes older and fatter. Less energy is therefore required to produce these early gains in weight. Also, since young animals eat considerably more feed per 100 lbs. live weight than do older ones, they have available for meat production a greater surplus of nutrients after their maintenance requirements are met.

As has been stated previously, these factors fully account for the lower cost of the gains made by young animals. Though they require less feed per 100 lbs. gain and therefore make cheaper gains, young animals do not utilize any more efficiently the feed consumed beyond the amount they need to maintain their bodies. As a matter of fact, in Missouri experiments where the entire carcasses of pigs were analyzed at various stages of growth up to 300 lbs. live weight, the older pigs apparently required slightly less feed than the younger ones per therm of energy in the gains they made.[1]

From a study of the results of various feeding experiments, a special committee of the National Research Council states that thrifty pigs fed modern, efficient rations will consume about the amounts of feed per head a day and make the daily gains shown in the following table.[2] The feed required per 100 lbs. gain is shown in the last column.

The rates of gain and the feed efficiencies shown in this table can be secured only when well-bred pigs are fed

first-class rations and when the care and management are excellent.

Feed consumed, gain, and efficiency at various weights

Live weight Lbs.	Air-dry feed Lbs.	Daily gain Lbs.	Feed per 100 lbs. gain Lbs.
25	2.0	0.8	250
50	3.2	1.2	267
100	5.3	1.6	331
150	6.8	1.8	378
200	7.5	1.8	417
250	8.3	1.8	461

The table shows that the daily gain increases until the pigs reach about 150 lbs. The amount of feed required per 100 lbs. gain steadily increases as the pigs grow older and fatter. If carried to a heavier weight than 250 lbs., the gain will commonly be less rapid than before, and the efficiency of gain will be considerably lower.

Studies by the United States Department of Agriculture in cooperation with several experiment stations show a very important fact.[3] This is that although the amount of feed required per 100 lbs. gain *during each period* steadily increases, the total amount of feed required per 100 lbs. of *total weight of pigs* decreases until a weight of about 200 lbs. is reached. Up to this time, the increase in feed required per 100 lbs. gain is more than offset by the fact that the large amount of feed needed to produce a pig up to weaning time, is distributed over a greater final live weight.

In this study the following amounts of total feed were required per 100 lbs. weight at the end of each period: To a live weight of 100 lbs., 496 lbs. feed per 100 lbs. of pigs; to a weight of 150 lbs., 459 lbs. feed per 100 lbs. of pigs; to a weight of 200 lbs., 448 lbs. feed per 100 lbs. of pigs; and to a weight of 250 lbs., 450 lbs. feed per 100 lbs. of pigs. These amounts include the feed eaten by the breeding herd, which must be charged to the pigs, and also the feed consumed by the pigs up to weaning time. (**1493**)

Pigs of small, early-maturing type become excessively fat before they reach such heavy weights. They then require much more feed per 100 lbs. of total weight than larger-type pigs.

It is emphasized later that when full use is made of good pasture the amounts of grain and supplements needed per 100 lbs. of gain are considerably less, thus decreasing the cost of pork production. (**1453**)

1380. Weight at which to market pigs.—Under normal conditions, most pigs are marketed in the United States when weighing 225 lbs. or less. This is largely because our consumers have a decided preference for rather small cuts of pork that do not carry too much fat. Pigs that yield such pork therefore command a premium over those that are heavier and fatter, unless there is an unusual demand for lard on the market. At present, we have a surplus of animal fats, instead of a scarcity.

When pigs are carried to heavy weights, the dressing percentage increases, as is shown later. (**1445**) Also, the percentage of edible product in the carcass increases slightly. However, after a weight of 200 to 225 lbs. is reached, more than two-thirds of the additional edible product will be fat, and less than one-third lean meat.[3]

To some extent, the proportion of fat in such heavy pork cuts as loins, hams, and shoulders can be standardized by trimming off the excess fat, which is then processed for lard. However, even the lean meat from over-fat hogs has too much fat to suit most of our consumers.

II. Nutrient Requirements of Swine

1381. Importance of efficient rations.—When swine are improperly fed, they are apt to suffer from severe nutritive deficiencies much more frequently than are cattle, sheep, or horses. One reason for this is because they are fed chiefly on grain in such countries as the United States, and they consume relatively little roughage, except when on pasture. For cattle, sheep, and horses, good roughage can largely and sometimes entirely meet their needs for protein, minerals, and vitamins.

Swine also grow more rapidly than

these other animals, and they produce young when less mature. Their requirements for protein, minerals, and vitamins are consequently increased.

Differing from cattle, sheep, or horses, swine need high-quality protein in their rations. This is because there is little synthesis of good-quality protein in their digestive tracts, such as occurs in the rumen of cattle and sheep and in the caecum and large intestine of horses. (**112**) Similarly, the B-complex vitamins are synthesized in the digestive tracts of swine to a far less extent than in the case of these other animals. Because of these facts, in order to secure good returns from swine, they must be fed rations that fully meet their nutrient needs.

The hundreds of nutrition and feeding experiments conducted during the past score of years have revealed in detail the needs of swine for maximum production. These experiments have proved that it is exceedingly important to provide swine, especially the breeding herd and young pigs, with good pasture whenever possible. When pasture is not available, well-cured alfalfa or other legume hay is the most economical substitute.

The most recent development in increasing the efficiency of pork production is the use of an antibiotic feed supplement to increase the rate of gain and reduce the feed required per 100 lbs. gain by growing and fattening pigs. (**1422**)

The great differences in the results from an inefficient ration and from a modern, complete ration were well shown by a recent Minnesota demonstration with pigs in dry lot.[4] Spring pigs fed an efficient ration from weaning until they reached 200 lbs. in weight, gained an average of 1.81 lbs. a day and required only 291 lbs. corn and 52 lbs. of complete supplement per 100 lbs. gain. Other pigs from the same litters, fed corn, tankage, minerals, and vitamin A-D supplement, but with no alfalfa hay, gained only 1.20 lbs. a day and required 13 per cent more feed per 100 lbs. gain. Still other pigs were fed corn with no protein supplement, but with supplements supplying minerals and vitamins A and D. On this unbalanced ration the pigs made very low gains, only 0.45 lb. a day, and required more than twice as much feed per 100 lbs. gain as did the pigs fed the modern ration.

1382. Feeding standards; digestibility of feeds by swine.—The amounts of dry matter, digestible protein, total digestible nutrients, calcium, phosphorus, and carotene advised per head daily for the various classes of swine are stated in the Morrison feeding standards in Appendix Table III. For those desiring to compute rations according to the net-energy system, net-energy allowances are also given. The standards for growing and fattening pigs are for those that are full-fed, so as to make rapid gains in weight.

These standards are designed for use with the values for digestible nutrients in various feeds that are given in Appendix Table I. Relatively few digestion trials have been conducted with swine, in comparison with the large number that have been carried on with ruminants. It therefore seems wiser to the author to use in computing rations for swine the digestible nutrient values in Appendix Table I, than to use a separate set of values, computed from the limited data obtained in digestion trials with swine.

There is not much difference in the ability of swine and of ruminants to digest concentrates that are not high in fiber.[5] Because of the great difference in the digestive tracts, swine digest a much smaller percentage of the fiber in feed than do cattle or sheep, or even horses.

This difference is not important in the case of most concentrates, for they are relatively low in fiber. However, swine digest hay and other roughages much less completely than do ruminants. It is for this reason, as well as because of the limited capacity of their digestive tracts, that swine are not able to make as much use of roughage as do cattle, sheep, or horses. Pigs have much less ability to utilize roughage than do older swine, such as brood sows.

The Morrison standards are based on studies by the author of the available data concerning the nutrient requirements of the various classes of swine.

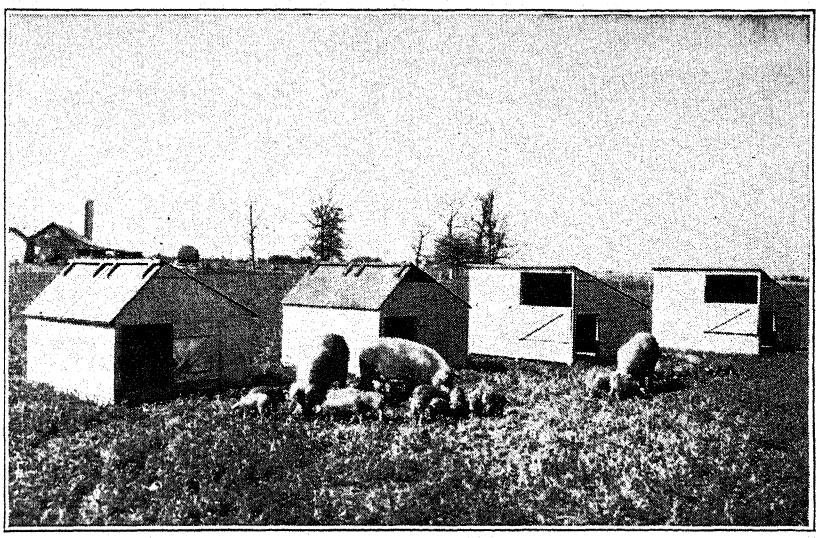
Due consideration has also been given to the feeding standard recommendations that have been made by other scientists,[6] especially to the report made by the special committee of the National Research Council, which has been mentioned previously.[2]

1383. Importance of good pasture or legume hay.—Wherever possible, swine should be provided with good pasture during the growing season and with well-cured legume hay when pasture is not available. These are especially needed for young pigs and for brood sows. Nothing is more important in reducing the cost of pork production and in preventing nutritive deficiencies.

As is explained later, there will generally be no deficiencies of vitamins when swine are fed sufficient well-cured legume hay or when they are on good pasture. (1406)

These feeds also aid greatly in meeting the protein requirements. This is because actively-growing pasture crops and also legume hay are fairly rich in protein, and the protein of these forages is of such kind that it helps to correct the deficiencies in the protein of the cereal grains. Legume hay and legume pasture crops are also very rich in calcium, and other good swine pasture crops supply much more calcium than do any of the grains or the grain by-products.

In addition to these virtues, good pasture amply meets the vitamin needs of swine. Legume hay of excellent quality supplies plenty of carotene, and if it is field-cured it also furnishes vitamin D. Fully as important, good pasture and high-quality legume hay provide B-complex vitamins and certain unidentified vitamins or factors needed by swine. (1415)



GOOD PASTURE PREVENTS NUTRITIVE DEFICIENCIES

Serious nutritive deficiencies may occur when sows are kept continuously in dry lot, even when well-balanced rations are fed. These deficiencies are prevented by good pasture.

Full-fed growing and fattening pigs do not consume a large amount of dry roughage, even of excellent legume hay. Therefore, when pigs are fed liberally on corn or other low-protein grain, they cannot eat enough of such roughage to balance the ration completely in protein content. In order to secure rapid and economical gains, a sufficient amount of an efficient, concentrated protein supplement must hence be added to furnish the proper amount of protein and also to supply protein of excellent quality. (1385–1391)

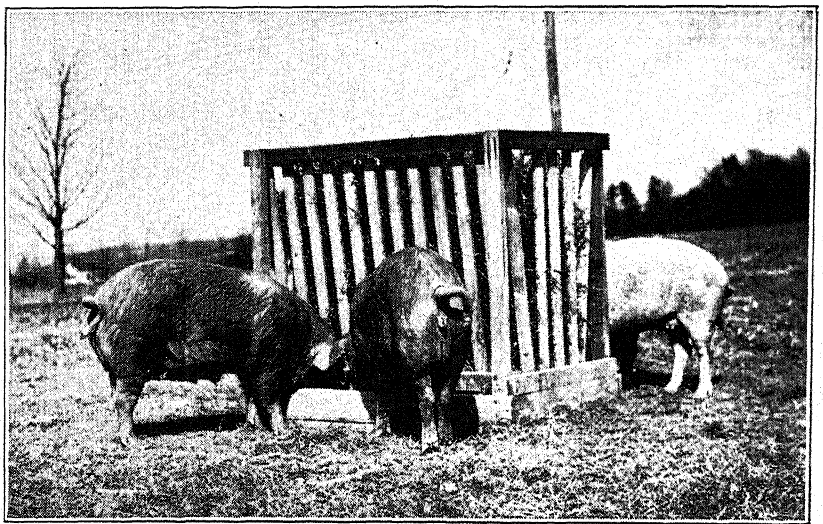
During the growing season, good pasture should be provided for swine, especially for young pigs and for brood sows, because green forage and pasture conditions are definitely superior to legume hay in meeting their nutritive essentials.

1384. Serious deficiencies with continuous dry-lot feeding.—Several investigations have shown that it is hazardous to confine swine continuously to a dry lot, without providing any pasture or other green feed.[7] In these experiments serious nutritive deficiencies have often developed when brood sows have been raised in dry lot and kept there continuously.

This has occurred even when rations were fed that would have been entirely satisfactory for sows which were on pasture part of the year. Many of the pigs from the sows kept continuously in dry lot were born weak or dead. Also, the milk of the sows was so deficient in amount or quality that a large proportion of the pigs born alive did not survive.

Such disaster even occurred when the sows were fed a well-balanced ration of yellow corn, tankage or fish meal, minerals, and 5 per cent of well-cured alfalfa hay or dehydrated alfalfa meal. The trouble is apt to be more serious when no protein supplement of animal origin, such as tankage or fish meal, is included in the ration. Such a supplement furnishes vitamin B_{12}, which is required by swine. (1414)

These deficiencies are entirely prevented by good pasture. Also, increasing the proportion of good alfalfa hay in the ration for sows to 10 to 15 per cent or even more is nearly as effective.



SWINE NOT ON PASTURE SHOULD HAVE LEGUME HAY

Well-cured legume hay provides insurance against lack of vitamins. These sows are provided with good alfalfa hay in the rack. (From J. P. Willman, Cornell University.)

The bad results are apparently due to the lack of certain vitamins. There has been a marked improvement when all the known B-complex vitamins have been added in pure form to the rations. However, increasing the alfalfa hay has been more beneficial than adding the pure B-complex vitamins. This indicates that the injuries are partly produced by a lack of certain unidentified vitamins or factors that are furnished by pasture and by excellent legume hay. These are discussed in a later article, and information is given concerning supplements that provide them. (1415)

Such deficiencies in dry-lot rations for sows are not prevented by adding a vitamin A-D supplement or any complex mineral mixture.

When pigs that are thrifty at birth are raised entirely in dry lot on a good ration, but without pasture at any time, nutritive deficiencies sometimes develop. This may occur even when the pigs are fed such a ration as yellow corn and a trio-type supplemental mixture. (**1418**) Some pigs may become unthrifty and fail to make normal gains, and they may become lame or be unable to walk normally, because of incoordination of movements.

Such troubles can nearly always be prevented by giving the pigs a good start on pasture. Increasing the percentage of first-rate alfalfa hay in the ration to 10 or 15 per cent also usually prevents the deficiencies. (**1417**)

The deficiency troubles with brood sows and pigs confined to dry lot seem to be less apt to occur when a liberal amount of skimmilk is fed. Thus, in an Arkansas experiment satisfactory litters were raised in 2 successive generations by sows confined to dry lot and fed yellow corn and skimmilk, with irradiated yeast as a vitamin D supplement.[8]

1385. Protein of good quality essential.—In swine feeding it is fully as important to provide protein of good quality in the ration as it is to supply a sufficient amount of protein. (**106**) This is especially necessary for young pigs and also for brood sows that are nursing litters.

None of the cereal grains furnishes protein of good quality, and the quality of protein in corn and the grain sorghums is apparently lower than that in wheat, barley, or oats. Skimmilk, other dairy by-products, fish meal, digester tankage, and meat scrap all provide protein that corrects the deficiencies of the protein in the cereal grains. Therefore any one of these feeds of animal origin can be used satisfactorily as the only protein supplement for swine. However, for swine not on pasture, legume hay should be included in the ration to provide vitamins.

It is shown later in this chapter that even better results are secured when pigs not on pasture are fed such a protein supplement as a trio-type mixture than when the only supplement is tankage or meat scrap. (**1418–1419**) Likewise, even for pigs on pasture certain combinations of tankage and protein supplements of plant origin may be more efficient or more economical than tankage as the only supplement to grain. (**1421**)

It has been emphasized in Chapter XXII that soybean oil meal which has been properly cooked in the manufacturing process is an excellent protein supplement for swine. (**805**) For swine on good pasture it is satisfactory as the only protein supplement, if a mineral mixture is supplied that furnishes calcium and phosphorus. For swine in dry-lot, legume hay should be included in the ration, as advised previously. Even better results are secured when soybean oil meal is used in one of the efficient protein supplements described later.

Peanut oil meal which is low in fiber ranks close to soybean oil meal as a protein supplement for swine, and may be used similarly. Peanuts and cooked soybeans also correct the deficiencies in the protein of the grains. However, both of these feeds produce soft pork when too much is included in the ration. (**1446–1447**)

Part of the protein needed to balance a ration for swine may be provided by a protein supplement that would not be satisfactory if used as the only supplement to cereal grains. For example, linseed meal or wheat middlings are very inefficient when used as the only protein supplement to corn for pigs in dry lot. However, when one of these supplements is used in combination with a limited amount of tankage, fish meal, or dairy by-products, excellent results are produced.

The value and use in swine feeding of the various protein supplements are discussed in detail in the chapters of Part II.

1386. Certain feeds unsatisfactory as only supplements.—Any ration made up of only corn or grain sorghum and grain by-products is very unsatisfactory

for pigs, even when a mineral mixture is supplied to furnish plenty of calcium and phosphorus and when there is no lack of vitamins A or D. For example, if pigs are fed yellow corn supplemented by wheat middlings, corn gluten feed, corn gluten meal, rye feed, brewers' dried grains, or distillers dried grains, they will make poor and expensive gains, even if they are out in the sunlight (which will supply vitamin D) and if they are fed a suitable mineral mixture to provide additional calcium and phosphorus.

The results will still be poor if the pigs are fed a mixture of corn and other grains supplemented by a combination of two or more of these protein-rich grain by-products. Thus, a combination of corn, barley, oats, wheat middlings, and corn gluten meal furnishes protein of unsatisfactory quality for swine.

Linseed meal is no more effective than wheat middlings as the only protein supplement to corn in swine feeding. Likewise, none of the following produces good results when used as the sole protein supplement to corn in swine feeding: Cottonseed meal, field peas, cowpeas, field beans, coconut meal, or buckwheat middlings. If the pigs are fed choice legume hay in addition to corn, these protein supplements will produce better results than without the legume hay. However, especially in the case of young pigs, the gains will be much more rapid and economical if these supplements are combined with such supplements of animal origin as tankage, fish meal, or dairy by-products.

Excellent pasture, like alfalfa, clover, or rape, furnishes a considerable amount of protein of good quality. On excellent pasture, even young pigs make fairly good gains on a ration consisting of corn, a suitable mineral mixture, and such a protein supplement as linseed meal or wheat middlings. However, it generally pays to include a more efficient protein supplement in the ration.

Experiments have shown that linseed meal or field peas are more satisfactory as the only protein supplement to barley or wheat for pigs in dry lot, than as the only protein supplement to corn. (835, 855) This shows that better quality protein is provided by the combination of wheat or barley with one of these supplements than by the combination of corn with the same supplement.

1387. Amounts of protein required.—Because of their rapid growth, pigs need rations containing liberal proportions of protein. Unless care is taken to meet this requirement, they will make slow and expensive gains.

Young pigs require a much greater proportion of protein than do those which are older and are therefore storing less protein and more fat in their bodies. (259) Often this fundamental fact is overlooked, and pigs are fed the same proportion of protein supplement from weaning time to market. If there is enough protein supplement in the mixture to produce good growth when the pigs are young, there will be considerably more than is needed after they reach weights of 100 to 125 lbs. On the other hand, if only a small proportion of supplement is used throughout the entire period, the pigs will have too little protein while they are young to make rapid and efficient gains.

Several recent experiments have proved that if a ration furnishes ample minerals and vitamins, growing and fattening pigs need considerably less protein to produce rapid and efficient gains than was formerly thought necessary.[9] The greater gains of the pigs on higher levels of protein in the earlier experiments seem to have been due to the larger amounts of B-complex vitamins provided by the high-protein rations, rather than to more protein itself.

The amounts of digestible protein recommended in the revised feeding standards for growing and fattening pigs in Appendix Table III are based upon the results of these recent experiments.

The protein requirements of brood sows during pregnancy and during lactation are discussed in the next chapter. (1456)

1388. Percentages of total protein needed in swine rations.—Swine are often fed a mixture of ground grain with the proper proportion of protein supple-

ments and also mineral and vitamin supplements. In making up such mixtures it is therefore convenient to know the percentage of total protein (not digestible protein) needed in the entire ration.

The special committee of the National Research Council has recommended, in its report on "Nutrient Requirements of Swine," that rations for growing and fattening pigs should have the following percentages of total protein: At a weight of 25 lbs., 18 per cent; at 50 lbs., 16 per cent; at 100 lbs., 14 per cent; at 150 lbs., 13 per cent; at 200 lbs. and above, 12.0 per cent.[2]

For pregnant females and breeding boars the committee has recommended a total protein content of 15 per cent for young stock and 14 per cent for adults. For lactating sows the recommended percentages are 15 per cent for gilts and 14 per cent for adult sows.

Swine on alfalfa or other protein-rich pasture of course need less protein in the concentrate mixture than do those in dry lot. The proportions of protein supplements required on pasture are indicated in the example rations given in Appendix Table VII.

In the recent experiments on protein requirements of growing and fattening pigs, which have been mentioned previously, sometimes rapid and efficient gains have been made on rations containing even less protein than advised by the committee. However, low levels of protein tend to produce more fat and less lean in the carcass. This is undesirable from the standpoint of the preference of our consumers for leaner pork cuts.

The protein requirements of swine are actually chiefly requirements for sufficient amounts of the various essential amino acids, rather than a need for a certain amount of protein. Therefore a lower percentage of protein will produce good results when the protein is of excellent quality. For example, in an Illinois experiment weanling pigs made rapid gains on a ration having only 10.2 per cent protein, in which dried skimmilk furnished practically all the protein.[10]

When protein supplements are unusually high in price in comparison with the cost of grain, it may be most economical to feed a smaller amount of supplement than is needed to produce the most rapid gains.[11] The law of diminishing returns applies here, as it does in many phases of animal husbandry. (**1025**) When added to a concentrate mixture that has just enough protein to keep pigs thrifty, each additional pound of protein supplement added successively to the mixture will have a lower value than the previous pound. Finally, when the mixture has sufficient protein to produce maximum gains, any additional amount of protein supplement will be worth no more per pound than farm grain. (**815**, Appendix Table II)

Catron of the Iowa Station has developed a convenient slide rule for finding the most economical proportion of soybean oil meal and corn for feeding pigs of various weights, with these feeds at different prices.[12]

1389. Amino acid requirements.—The approximate percentages of all of the 10 essential amino acids required in a ration for weanling pigs have been determined in recent careful experiments.[13] In these experiments various amounts of the amino acid being studied were added to a highly purified diet which was deficient in that amino acid. A very limited amount of such information has been thus obtained concerning

Amino acid requirements of weanling pigs

Amino acid	Percentage of total ration
L-Arginine [1]	0.20
L-Histidine	0.20
L-Isoleucine	0.70
L-Leucine	0.60
L-Lysine	1.00
DL-Methionine [2]	0.22
DL-Phenylalanine	0.46
L-Threonine	0.40
DL-Tryptophan	0.20
L-Valine	0.40

1 This level is adequate but the minimum requirement has not been determined.

2 This percentage of methionine is ample when a ration has the usual amount of cystine, which can partially replace methionine.

the amino acid requirements of baby pigs.[14] Similar investigations have not been conducted with well-grown pigs.

The preceding table states the approximate amounts of the different essential amino acids needed for growth by weanling pigs.

The percentage of protein needed in the diet for baby pigs is higher than for weanling pigs, and also the percentages of the essential amino acids.

1390. Correcting amino acid deficiencies.—Several experiments have been conducted recently with weanling pigs to find whether there were any amino acid deficiencies in certain practical rations.[15] In these studies the effect was determined of adding definite small amounts of the amino acid or amino acids that might possibly be deficient in the ration being tested.

From these studies and other data, especially the information concerning the percentages of the essential amino acids, given in Appendix Tables VIIIa and VIIIb, certain conclusions can be drawn. It must be borne in mind that the data concerning the minimum requirements for the essential amino acids are still limited, and that such tables as Appendix Tables VIIIa and VIIIb can show only the approximate content of the amino acids in various feeds.

First of all, the available data indicate there is not apt to be a deficiency of any amino acid in a ration where the protein comes from 3 or more good sources, and where a considerable part is supplied by such feeds as soybean oil meal, fish meal, or dairy by-products. This is especially true when alfalfa hay or alfalfa meal is included in rations for pigs not on pasture.

A ration in which all the protein is furnished by corn grain and meat scrap or tankage is decidedly deficient in tryptophan for young pigs. This is shown by the fact that a combination of 84 lbs. corn (Grade No. 2) and 16 lbs. meat scrap (55 per cent protein grade) will have 16 per cent protein, thus meeting the total protein requirement of weanling pigs. However, the corn-meat scrap mixture will have only about one-half as much tryptophan as young pigs need.

The required amount of tryptophan could be supplied by adding the pure amino acid, but it is far too expensive to be used in a practical ration. Therefore some natural protein supplement which is rich in tryptophan should replace part of the meat scrap.

Soybean oil meal, wheat standard middlings or shorts, and alfalfa hay or meal all have twice as much tryptophan, per pound of protein, as does meat scrap. (Appendix Table VIIIb.) Including sufficient amounts of these feeds in the ration will hence correct the tryptophan deficiency.

A ration of corn, meat scrap, soybean oil meal, and alfalfa will often furnish a little less methionine than the requirement stated in the preceding table. However, as shown later in this chapter, such a ration produces excellent results with young pigs, without any addition of methionine. (**1418**)

A ration in which corn and low-gossypol cottonseed meal furnish all the protein is somewhat low in lysine and also in methionine for young pigs. It will be greatly improved by substituting soybean oil meal, meat scrap, tankage, fish meal, or fish solubles for part of the cottonseed meal. Further improvement will be made by including alfalfa for pigs not on pasture. The protein in all these feeds has much more lysine than there is in cottonseed meal protein.

The results of the experiments have differed in which pure amino acids have been added to rations in which all of the protein has come from corn and soybean oil meal. In some trials adding lysine or methionine has been beneficial, but not in other tests. However, as is pointed out in Chapter XXII and also later in this chapter, the best results for young pigs in dry lot are usually secured when soybean oil meal is combined with such a supplement as meat scrap, tankage, or fish meal.

Milo and possibly other grain sorghums are even lower than corn in lysine. Therefore it is especially important to correct this lack by protein supplements rich in this amino acid.

As pointed out in Chapter V, methionine is the only pure amino acid yet available at a low enough price to warrant its use in practical rations. (128) Adding 1 lb. of methionine per ton to a formula feed would increase the methionine content 0.05 per cent at a cost of not over $3.00 per ton.

1391. Self-feeding protein supplements free-choice.—Pigs show a remarkable ability to balance their rations in protein when they are self-fed corn or other low-protein grains and also self-fed separately *certain* single protein supplements or *certain* supplemental mixtures. At early ages they eat enough of such a supplement to balance their ration, and then gradually eat a smaller proportion of supplement as they grow older and their need for protein is less.

This free-choice plan usually works excellently with pigs on pasture or in dry lot fed tankage, meat scrap, or fish meal as a single supplement to corn or sorghum grain, or when a trio mixture or a similar combination is self-fed with these grains. (**1418–1420**)

Occasionally, the pigs may eat somewhat more supplement than they need, and once in a while they may not consume as much of the supplement as they should. However, the results from the free-choice method of feeding these supplements with corn will average fully as good or better than when time is taken to mix the proper proportion of supplement with ground corn or to hand-feed the supplement.

The free-choice plan of self-feeding grain and protein supplement is not so well suited for use with barley, oats, or rye. With these grains less protein supplement is needed than with corn, for they contain somewhat more protein. However, the pigs often eat fully as much of the supplement as when they are self-fed corn. To avoid wastage of the protein supplement it is therefore necessary to mix the proper proportion of the supplement with the ground grain, or else to hand-feed the amount of supplement that is actually needed to balance the ration. Wheat is so palatable to pigs that they generally do not eat more than they need of such a protein supplement as tankage or fish meal, when they are self-fed wheat and the supplement, free-choice.

When pigs are self-fed, free-choice, corn and certain protein supplements or supplemental mixtures, they are apt to eat much more of the supplement than they need, especially if they are on good pasture. This may occur with soybean oil meal or with such a mixture as one-half soybean oil meal and one-half meat scrap or fish meal.

In such a case, ground legume hay, salt, or mineral supplement can be mixed with the protein supplement in a proportion that will make the correct reduction in the amount eaten. Another way of preventing waste of protein supplement is to hand-feed just enough to balance the ration.

1392. Protein supplement needed in dry-lot.—Many experiments years ago proved that growing and fattening pigs in dry lot cannot make satisfactory gains or even remain thrifty on grain alone, without a protein supplement. Even when grain is fed with a mineral supplement, but without additional protein, the gains are slow and expensive. Sometimes the pigs will become runts or even die because of the inadequate ration.

Balancing the ration by the addition of a good supplement will double the rate of gain in the case of young pigs. Also, each 100 lbs. of protein supplement will save 500 to 600 lbs. or more of corn, without considering the advantage of the more rapid gains.

After pigs in dry lot have reached a weight of 175 to 200 lbs., they may make fair gains on corn without a protein supplement, because their requirements for protein are then not high. However, the gains are usually much more rapid and also somewhat more economical when the use of a good supplement is continued until the pigs are marketed.[16]

On barley, wheat, or oats as the only feeds, or on these grains plus a mineral supplement, the gains may be somewhat better than on corn, because these grains supply more protein and protein of somewhat better quality than does

corn. However, in the case of pigs not on pasture, the gains are greatly increased by the addition of a sufficient amount of a good protein supplement to balance the ration.

Adding alfalfa hay or other legume hay to corn for pigs not on pasture will generally permit fair gains and prevent serious nutritional trouble. However, as has been shown in Chapter XVI, the gains on only corn and alfalfa hay are much less rapid and usually more expensive than when such a supplement as tankage or soybean oil meal is also fed. (464)

Because barley, wheat, and oats are higher than corn in protein, the results are somewhat better when alfalfa hay is fed as the only supplement to these grains. However, unless tankage and other efficient protein supplements are unusually high in price, it generally pays to add a limited amount of such a supplement to a ration of any of these grains and good-quality alfalfa hay, especially for pigs under 100 to 125 lbs. in weight.[17]

1393. Feeding a protein supplement on pasture.—When pigs are on first-class pasture, considerable protein and protein of fairly-good quality is provided by the green forage they eat. Pigs will therefore make fair gains when full-fed corn on such pasture, without any protein supplement, especially if a mineral mixture is provided to furnish plenty of calcium and phosphorus.

However, pigs will not eat enough pasturage in addition to a full feed of corn to balance their ration completely. The rate of gain will therefore be considerably increased by adding an efficient protein supplement. Nevertheless, each 100 lbs. of the supplement will save a much smaller amount of corn than when fed to pigs not on pasture.

In the case of early spring pigs, the increase in the rate of gain produced by the supplement is more important than the saving of corn. If such pigs are full-fed on corn plus a good supplement, they can be brought to market weights before the severe slump in hog prices which usually occurs in late autumn. (1427) On the other hand, if no supplement is fed it will take at least 2 to 4 weeks longer to get them to the same weights, and during this time the price may decline 50 cents or more per hundredweight. Because of the difference in selling price, it will usually be most profitable to feed a supplement if pigs can thereby be hurried to market early in the fall.

Whether or not to feed a supplement to later pigs will depend on the age of the pigs, on the rate of gain that is desired, and on the relative price of corn and of supplements. Except when supplements are high in price in comparison with corn, it is probably best to feed a supplement until the pigs reach a weight of at least 100 lbs.

Because Ladino clover pasture is especially rich in protein and also very palatable to pigs, there is less advantage from feeding a protein supplement than with pigs on most other pastures.[18]

Unless the pasture is excellent, good gains cannot be secured without a supplement. Thus, there is more advantage in feeding a supplement to pigs on grass pasture (such as bluegrass, timothy, or Sudan grass) than to pigs on excellent legume or rape pasture.[19]

The benefits from using tankage or some other efficient supplement for pigs full-fed corn on good pasture and also supplied with a mineral mixture, are shown by the results of 23 experiments.[20] In these trials pigs which averaged 64 lbs. in weight at the start were full-fed corn up to market weights on legume or rape pasture, and in addition were provided with a mineral mixture that supplied calcium and phosphorus.

The pigs fed tankage or another efficient supplement gained an average of 1.53 lbs. per head daily and required only 310 lbs. corn, 26 lbs. tankage or tankage equivalent, and 3 lbs. mineral mixture per 100 lbs. gain. Those fed no protein supplement gained 1.32 lbs. per head daily and required 352 lbs. corn, 4 lbs. mineral mixture, and 0.5 lb. tankage equivalent per 100 lbs. gain. (In a few trials the pasture became exhausted a few days before the pigs were ready for market. A protein supplement was

then fed to the pigs which had received no supplement previously.)

In these experiments each 100 lbs. of tankage or tankage equivalent saved only 161 lbs. corn plus 4 lbs. of mineral mixture, if no value is placed on the difference in rate of gain. The pigs fed the protein supplement also undoubtedly ate a little less pasturage.

If no mineral mixture is provided for pigs full-fed corn on good pasture, there is a somewhat greater advantage in adding a protein supplement. For example, adding tankage to this ration for pigs averaging 60 lbs. in weight at the start increased the daily gain from 1.13 lbs. to 1.46 lbs., on the average, in 27 experiments.[21] In these numerous trials each 100 lbs. of tankage saved an average of 282 lbs. corn, not considering the difference in rate of gain.

Experiments have shown that for pigs on good pasture that are fed barley, wheat, oats, or rye (which contain more protein than does corn) there is less benefit from adding a protein supplement.[22] After pigs fed these grains reach a weight of about 100 lbs., it does not usually pay to add a supplement, unless maximum gains are desired. Up to this weight, it is generally best to feed a small amount of supplement, unless the pasture is unusually good or protein supplements are high in price. With these grains, pigs on pasture will often eat too much of the supplement if it is self-fed, free-choice. The proper proportion should therefore be mixed with the ground grain, or a small amount of the supplement should be hand-fed daily.

EXCELLENT PASTURE BALANCES THE RATION

After pigs reach a weight of 100 to 125 lbs. they make good gains when fed only corn and a mineral supplement on excellent pasture, such as this alfalfa pasture.

When the pasture is good, 4 lbs. of tankage or fish meal of usual grades are enough per 100 lbs. of these grains for pigs under 100 lbs. in weight. If a supplement is fed to older pigs, not over 2 to 3 lbs. of tankage or fish meal per 100 lbs. of grain are advisable. When the supplement is hand-fed to pigs getting barley, oats, wheat, or rye on good pasture, 0.2 lb. per head daily of tankage or fish meal is sufficient.

If pigs are fed only a limited amount of grain on good pasture, they will eat more of the green forage than when full-fed on grain. There will therefore be less benefit from adding a protein

supplement to the ration, and under usual conditions it will not pay to use a supplement, even when the grain is corn.[23]

1394. Feeding no protein supplement to well-grown pigs.—For pigs on good pasture, most of the advantage from feeding a supplement to corn and minerals can be gained by using the supplement only until the pigs reach a weight of 100 to 125 lbs. Unless one wishes to get early spring pigs to market before the price drops in the fall, this method will usually be more economical than to feed the supplement until the pigs are marketed.

In 6 experiments pigs on good pasture gained an average of 1.59 lbs. a day when fed a protein supplement to corn and minerals only up to a weight of 100 to 125 lbs., and then fed only corn and minerals.[24] When the supplement was fed until the pigs were ready for market, the average daily gain was 1.72 lbs. The average cost of feed per 100 lbs. gain was 31 cents less when no protein supplement was fed during the final period. In these trials each 100 lbs. of protein supplement that was fed after the pigs reached a weight of 100 to 125 lbs., saved only 95 lbs. corn and 5 lbs. of mineral mixture.

1395. Fat; addition of fat to rations.—Normal rations of grain and protein supplements will always supply enough fat for efficient gains by growing and fattening pigs, even when the chief protein supplement is a solvent-process oil meal. While the minimum fat content of practical rations is therefore not important, soft pork is produced if the ration has too large a percentage of a kind of fat which produces soft body fat. The extent to which such softening feeds as soybeans or peanuts can be fed without producing soft pork is discussed later in this chapter. (**1446–1447**)

Pigs fed experimental rations containing but 0.5 per cent of fat made satisfactory gains and stored a normal amount of body fat.[25] This is far less than there is in any practical ration. However, pigs apparently require a certain very small amount of fat. (**133**) In Indiana experiments when young pigs were fed highly-purified rations having only 0.06 to 0.12 per cent of fat, characteristic symptoms of fat deficiency developed.[26] These included unthriftiness, scaly, dandruff-like dermatitis, and necrotic areas on the skin. Adding only 1.5 per cent of corn oil to the ration brought recovery.

Because of the low price of surplus by-product animal fats during recent years in this country, experiments have been carried on to find the effects of adding such fats to ordinary rations for growing and fattening pigs.[27] Adding up to 10 per cent of such grease or tallow to the ration has slightly increased the gain in some trials, but not in others. Such a fat addition tends to increase the proportion of fat in the carcass, which is undesirable.

Adding fat to the ration may decrease slightly the amount of feed required per 100 lbs. gain, because of the high energy value of fat. Whether the addition will be economical depends on the price of such fat in comparison with the cost of grain.

The firmness of the fat in the carcass is increased by adding tallow to the ration, but adding grease has the opposite effect.

1396. Total digestible nutrients; fiber.—Swine have only limited capacity to consume roughage, and they do not digest the fiber of feeds well. Consequently, to produce rapid gains the rations of growing and fattening pigs must consist chiefly of grain and other concentrates. Because brood sows have more capacious digestive tracts, they can utilize a somewhat larger proportion of such excellent roughage as alfalfa hay. (**1460**)

The total digestible nutrient requirements and also the desirable amounts of dry matter for swine of various classes are shown in the Morrison feeding standards. (Appendix Table III.)

Growing and fattening pigs usually make the most rapid gains and require the least feed per 100 lbs. gain when their rations do not contain more than about 5 to 6 per cent of fiber.[28] It is therefore not generally economical to use rations having a higher percentage of

fiber for such pigs, unless the prices of corn, barley, wheat, or other feeds low in fiber are very high in comparison with the prices of feeds higher in fiber, such as oats or legume hay.

This is shown by the experiments in which oats have been compared with corn for growing and fattening pigs. It has been shown in Chapter XX that when ground oats do not form more than one-fourth of the ration for pigs in dry lot, oats are worth about as much as corn per 100 lbs. (**725**) On the other hand, when oats are fed as the only grain, they are worth only 79 per cent as much as corn.

Reducing the net-energy intake of pigs, especially during the last third of the growing and fattening period, will produce leaner carcasses than full-feeding a concentrated ration. This is important where a considerable premium is paid, as in Canada, for pigs that yield high-quality bacon carcasses.

The energy intake can be restricted by hand-feeding only enough of the concentrate mixture to produce the desired rate of gain. However, when this is done, the greediest pigs may get more than their share, and consequently become too fat. As is pointed out later in this chapter, the energy supply to all of the pigs can be restricted more uniformly by including in the concentrate mixture a sufficient amount of some feed that is high in fiber, but still is nutritious. (**1431**)

It is emphasized elsewhere in this chapter that it is important to include alfalfa or other legume hay in the rations for swine not on pasture, especially for brood sows and for young pigs. (**1383, 1417**) Except possibly when legume hay is very cheap in comparison with grain, the desirable proportion of legume hay for growing and fattening pigs is from 5 to 15 per cent, depending on the danger of vitamin deficiencies in the ration. The proportion of legume hay for brood sows can be higher, as shown in the next chapter. (**1460**)

Recent Nevada experiments have been conducted to find how much very early-cut, excellent-quality alfalfa hay, having not over 25 per cent fiber, could be satisfactorily included in rations for growing and fattening pigs.[29] Young pigs were early accustomed to a considerable proportion of such alfalfa by including 25 per cent in the creep-fed mixture. This apparently enlarged the capacity of the digestive tract for roughage.

From weaning time to market, pigs made fair gains on rations having as much as 50 per cent of the unusually good alfalfa hay. In 2 trials pigs gained 1.10 lbs. per head daily on such a ration, in comparison with 1.45 lbs. gain made by pigs fed a normal ration. On the high-alfalfa ration 20 per cent more feed was required per 100 lbs. gain.

1397. Minerals.—It is shown in the following articles that the minerals which commonly need consideration in swine feeding are salt, calcium, and phosphorus. In iodine-deficient areas, brood sows need iodized salt or some other iodine supplement to prevent hairless pigs. To avoid anemia when suckling pigs are confined without access to pasture or soil, traces of iron and copper must be supplied by such a method as is described later.

The addition of trace minerals to rations has been discussed in Chapter VI and further information is given later in this chapter. (**1404**)

1398. Salt.—Although swine need less salt than do cattle, horses, or sheep, they should be supplied with it regularly, unless the feeds in the ration furnish enough. The best plan is to let them have access to salt in a suitable box or trough. When salt is thus fed, pigs will eat as much as 0.3 ounce per head daily.

Swine are apt to eat less block salt than flake salt. When block salt is used, it is best to include 20 per cent of salt in the calcium-phosphorus mineral mixture, if such a mixture is also provided. When salt is mixed with the entire ration, not over one-half pound of salt should be added to each 100 lbs. of feed. If pigs have not had salt for some time, they may at first eat too much if given free access to it.

When tankage, meat scrap, or fish meal is fed as the only or the chief protein supplement, there may be little or

no benefit from supplying additional salt, because of the salt these feeds normally contain.[30] On the other hand, it is very necessary to provide salt for swine fed a ration made up wholly or almost entirely of feeds which are of plant origin.

The great benefit from adding salt to such rations is well shown by recent Indiana and Wisconsin trials.[31] In 2 Indiana experiments pigs made an average daily gain of only 0.86 lb. and required 562 lbs. of feed per 100 lbs. gain when fed yellow corn, soybean oil meal, and a mineral mixture containing no salt. Other pigs supplied salt in addition gained 1.61 lbs. and needed only 363 lbs. of feed per 100 lbs. gain. The benefit from supplying salt was somewhat less in a similar Wisconsin test.

From Wisconsin experiments it was concluded that rations for growing and fattening pigs should have 0.08 to 0.10 per cent sodium and 0.12 to 0.13 per cent chlorine.[32] Though the requirement for chlorine is apparently slightly higher than for sodium, the chief deficiency in a ration of grain with plant protein supplements is sodium, rather than chlorine. This is because the grains contain considerably more chlorine than they do sodium.

Salt poisoning of pigs may occur if pigs have access to brine or unusually salty whey, with no other water available.[33]

1399. Calcium.—With the exception of salt, calcium is the mineral nutrient that is most apt to be lacking in swine rations. This is because all the grains and their by-products and also practically all protein-rich concentrates of plant origin are low in calcium. Fortunately, tankage, meat scrap, fish meal, skimmilk, buttermilk, legume forage (pasturage and hay), and rape forage all are rich in calcium. Whether or not there will be any need of supplying swine with a calcium supplement will therefore depend entirely on the ration that is fed.

In experiments at the Kansas Station with growing and fattening pigs, a calcium content of 0.45 to 0.50 per cent in the entire ration on the air-dry basis was sufficient when the ration had ample phosphorus and when the pigs were exposed to sunlight, so there was no deficiency of vitamin D.[34] In similar Wisconsin trials a calcium content of only 0.32 to 0.41 per cent was enough to prevent any symptoms of deficiency.[35] In Missouri studies it was concluded that the rations of brood sows should have at least 0.40 per cent of calcium.[36]

From the results of these and other experiments Bohstedt of the Wisconsin Station concluded that when swine have access to outdoor lots, so they have exposure to sunlight, growing and fattening pigs need no more than 0.45 per cent calcium and breeding stock 0.50 per cent.[37] The author has based the calcium allowances for swine in the feeding standards in Appendix Table III mainly on these conclusions.

Somewhat higher allowances have been recommended in the report of the special committee of the National Research Council which has been mentioned previously,[2] and also in a report from the Iowa Station.[38] The author has not placed his recommendations at these higher levels, because there seems to be no experimental evidence of any calcium deficiency occurring on the levels stated by Bohstedt.

The Wisconsin experiments show that it decreases the gains and the feed efficiency if too much calcium is added to a ration. Also, too much calcium tends to cause parakeratosis in pigs. (181)

The proportion or ratio between the amounts of calcium and of phosphorus is important in rations for swine. (152) From his and other experiments Bohstedt concludes that the calcium-phosphorus ratio should be between 1.1:1 to 1.5:1. In other words, there should be 1.1 to 1.5 parts of calcium to each part of phosphorus.

There will usually be no lack of calcium when swine are fed sufficient tankage, meat scrap, or fish meal to balance their rations. On the other hand, a calcium supplement is essential when corn or other grain is fed with a protein supplement low in calcium, such as soybean oil meal, linseed meal, or wheat

middlings. This is especially important for pigs not on pasture.

There is not likely to be a lack of calcium when swine are on legume or rape pasture, even when fed grain and a protein supplement low in calcium. However, pigs hogging down peanuts need a calcium supplement to prevent a serious lack of the mineral.[39] Ohio experiments indicate that for pigs not on pasture a ration of corn supplemented by the usual amount of skimmilk may not supply quite enough calcium for the best results with young pigs.[40]

1400. Phosphorus.—There is much less apt to be a lack of phosphorus in swine rations than of calcium, because most protein-rich supplements are rich in phosphorus. Also, though the cereal grains are not rich in phosphorus, they contain much more phosphorus than calcium. Tankage, meat scrap, and fish meal are especially rich in this mineral, and skimmilk, buttermilk, and wheat middlings, wheat bran, linseed meal, and cottonseed meal are also high in phosphorus. Soybeans, soybean oil meal, and peanut oil meal contain considerably more than do the cereal grains.

In Kansas and Illinois experiments a phosphorus content of 0.27 to 0.30 per cent on the air-dry basis was sufficient in rations for growing and fattening pigs which had ample calcium and when there was no lack of vitamin D.[41]

Bohstedt of the Wisconsin Station concludes from the results of his and various other experiments that in the case of swine with some exposure to sunlight by access to outside lots, 0.33 per cent of phosphorus is adequate for growing and fattening pigs and 0.40 per cent for breeding swine.[37]

The author has followed these recommendations in the main in the allowances of phosphorus stated in Appendix Table III, instead of higher levels stated in the report of the special committee of the National Research Council [2] or in a recent report from the Iowa Station.[38] He has done this because no phosphorus deficiency has been reported when swine, handled under practical conditions, have received only as much phosphorus as recommended by Bohstedt.

If swine have no exposure to sunlight and are fed a ration deficient in vitamin D, there should be a somewhat higher level of phosphorus in the ration.[42] However, this is not a practical way to feed swine.

Indiana and Iowa experiments show that phytin phosphorus, which forms a considerable part of the phosphorus in many feeds of plant origin, is not quite so well utilized by pigs, as is phosphate phosphorus, such as in bone meal or mineral phosphorus supplements.[43] (**151**) However, pigs apparently utilize phytin phosphorus much better than do poultry. In Wisconsin experiments growth, fattening, and reproduction were satisfactory on rations in which all the phosphorus came from grain and other plant sources, and the phosphorus level was no higher than previously stated.

Several experiments have shown that when corn or other grain is supplemented chiefly or entirely with soybean oil meal or soybeans, a mineral supplement should be added that furnishes both calcium and phosphorus.[44] The chief mineral deficiency in such a ration is calcium. However, the addition of ground limestone or another calcium supplement does not produce as good results as the use of bone meal or a combination of limestone and bone meal.

The various phosphorus supplements have been discussed in Chapter VI. (**158–169**) For continued feeding, a phosphorus supplement having a dangerous amount of fluorine should not be used as the chief source of phosphorus. When added to a phosphorus-deficient ration for pigs, soft phosphate with colloidal clay (colloidal phosphate) has in some trials produced less rapid growth than bone meal or dicalcium phosphate.[43] In an Iowa trial colloidal phosphate produced weaker bones than the other phosphorus supplements. In an Indiana experiment it caused pitting and decay of the molar teeth, because of the high content of fluorine.

1401. Adding calcium or phosphorus supplements.—Numerous experi-

ments have proved that there is generally no decided advantage in adding a calcium or phosphorus supplement to a well-balanced swine ration consisting of grain with tankage, meat scrap, fish meal, or skimmilk as the chief supplement.[45] In some cases, pigs have made slightly more rapid or economical gains when fed the mineral supplements in addition to salt, but in other tests there has been no benefit whatsoever from the calcium or phosphorus supplements. Similar results have been secured in experiments with brood sows and with gilts being raised for the breeding herd.

Since there has been a slight benefit from these mineral supplements in some cases, it may be wise to provide a suitable mineral mixture where swine can have access to it, even when they are fed such good rations. However, it should be understood that on these rations excellent results will be secured without the calcium and phosphorus supplements, and often there will be no advantage from their use.

There is more apt to be a slight benefit from the addition of mineral supplements to efficient rations for swine that are not on good pasture. Also, there is probably more advantage from providing such mineral supplements for brood sows and for young pigs fed good rations than for fattening pigs.

When there is a definite lack of calcium or phosphorus in the ration, then the mineral need must be met, or unsatisfactory results will be secured.[46] If the lack is pronounced, rickets will be caused and disaster may follow. Brood sows suffering from a serious deficiency of either of these minerals are unable to produce thrifty offspring. Many pigs will be born dead or weak, and the sows may be unable to provide an adequate supply of milk for those that appear normal at birth.

A supplement such as bone meal, which furnishes both phosphorus and calcium, should be provided when pigs on pasture are fed only corn or other grain, without any protein-rich concentrate, or when pigs in dry lot are fed only corn or grain sorghum with alfalfa or other legume hay.[47] A mineral supplement is less advantageous in the case of barley, wheat, or rye, as these grains contain somewhat more of these minerals.[48]

A good method of supplying a mineral supplement is to let the swine have access to a suitable mineral mixture in a box or self-feeder, so they can take as much as they desire. (186) Experiments have shown that it is unwise to mix with the concentrates a considerably greater amount of mineral supplement than is actually needed.

For example, in Texas trials pigs did better when 1 per cent of ground limestone was added to corn supplemented with a plant-protein supplement than when more limestone was added.[49] Similarly, in Wisconsin tests 1 per cent of bone meal or equal parts of ground limestone and bone meal gave better results than a larger amount of mineral supplement, when added to corn and soybean oil meal.[50]

It has been pointed out previously in this chapter that in swine rations it is important to have a proper calcium-phosphorus ratio. (1399)

1402. Iodine; prevention of goiter or hairlessness in pigs.—In regions where there has been trouble from goiter in new-born pigs, or so-called "hairless pigs," it can readily be prevented by supplying the brood sows with iodized salt instead of ordinary salt, during at least the last 12 weeks of pregnancy. (170) Even in border-line areas where there are rarely definite cases of hairlessness in new-born pigs, there may be a decided benefit from supplying the sows with iodized salt. (171)

In areas where there is definite lack of iodine and frequent cases of goiter in livestock, it is probably wise to use iodized stock salt instead of common salt for brood sows throughout the year and also to use this salt for growing and fattening pigs. On the other hand, there is no benefit from using iodized salt in areas where there is no deficiency of iodine.[51]

1403. Anemia in suckling pigs.—It has been explained in Chapter VI that

if suckling pigs are kept in pens or paved lots, away from contact with soil or sod, serious losses will often occur from anemia (lack of red blood cells) caused by a deficiency of iron and copper, unless special precautions are taken. (**174**) If the young pigs have access to pasture or even to the soil in an exercise plot, they begin to eat forage or to nibble at lumps of dirt within a few days after birth and thus get the exceedingly small amounts of these minerals necessary to prevent anemia.

When they do not have access to pasture or dirt, however, the number of red blood cells and the amount of hemoglobin in the blood decline rapidly, and often death results at from 3 to 6 weeks of age. In white pigs the anemic condition is clearly visible in the lack of a healthy pink color of such parts as the ears and nose. Anemic pigs usually have little appetite, are weak and inactive, and in severe cases breathe in the labored manner commonly described as "thumps." If they survive for 6 weeks, they usually recover from the anemia, because they then eat considerable food other than milk. However, pigs that have had anemia generally do not make good gains for a period of several weeks.

Anemia is especially apt to occur with pigs farrowed in the winter or early spring in the northern states, because the weather is then usually so cold that the young pigs do not get outdoors to any great extent. Also, they generally have no access to pasture, and the dirt in exercise paddocks may be covered with snow.

Several investigations have been conducted to find practical methods of preventing anemia in suckling pigs.[52] Anemia can readily be prevented by swabbing or spraying the udder of the sow regularly once daily with a saturated solution of ferrous sulfate or other soluble iron salt until the pigs are 4 to 6 weeks old, and also allowing them access to a palatable concentrate mixture, to each 100 lbs. of which has been added 0.1 lb. of the iron salt.

The iron solution may be prepared by dissolving as completely as possible 1 lb. of ferrous sulfate in a quart of hot water. The ordinary grade of ferrous sulfate supplies the very small amount of copper needed to prevent anemia. Another method is to give each pig a dose by mouth of the iron solution once a week.

A less bothersome method that generally prevents anemia is to put fresh sod or soil in the pen at frequent intervals. The pigs will usually root about this and nibble at it, thus getting the necessary traces of iron and copper.

Care should be taken to get the sod or soil from a spot where swine have not grazed for more than a year, to make sure that it does not carry the eggs of round worms or other parasites. Extremely sandy soil that is very low in iron should not be used, unless iron salt is sprinkled on it.

Anemia cannot be prevented by adding an iron salt to the ration fed the sow, because this does not increase the iron content of the milk. Also, adding an iron salt to the ration during pregnancy does not increase the store of iron in the bodies of the pigs at birth enough to prevent anemia.

1404. Trace minerals.—The different trace minerals have been discussed in detail in Chapter VI, and it is there pointed out that trace mineral deficiencies are area problems. In an area where there is a deficiency of cobalt, copper, or any other trace mineral, it is essential that the lack be corrected.

In areas where there are no trace mineral deficiencies, there is no need of supplying trace minerals for swine on good pasture. They undoubtedly secure plenty from the forage and the soil. Even in areas where there are no definite trace mineral deficiencies, there seems to be more often a benefit from a trace mineral supplement for pigs kept in dry lot, than there is in the case of cattle or sheep. This is probably because cattle and sheep eat so much more roughage.

In several experiments there have been increases in rate and efficiency of gains from adding trace minerals to well-balanced rations for pigs fed in dry lot.[53] However, in some trials there has been little or no benefit from supplying trace

minerals.[54] There is more apt to be an appreciable benefit from trace minerals with a ration containing no meat scrap, tankage, or fish meal, than when there is one of these animal products in the ration.

In the studies on trace minerals a mixture of these minerals has usually been fed, and consequently the information is limited as to which trace minerals have actually been beneficial, where improvement has occurred. In some trials where the effect of different trace minerals has been tested, a cobalt supplement or a combination of cobalt and copper has produced a definite benefit.

In some experiments with growing or fattening pigs there has been no benefit whatsoever from adding an iron supplement to ordinary rations, and in other tests the apparent benefit has been very slight.[55] It therefore seems doubtful whether such an addition will generally be profitable.

Information is given in Chapter VI concerning the manganese requirement of swine. (180) Also, the recent studies are there summarized which have shown that parakeratosis, a mange-like disease in pigs, can be prevented and cured by adding a zinc supplement to the ration. (181) As is stated there, a ration that has an excessive amount of calcium increases the occurrence of parakeratosis.

Trace minerals can be provided by using trace mineralized salt instead of ordinary salt. Also, the commercial mineral mixtures for swine now generally contain trace minerals.

1405. Simple vs. complex mineral mixtures.—Whenever swine are fed a ration that is definitely lacking in one or more of the essential mineral nutrients which have been discussed, the deficiency can readily be corrected by giving them access to a mineral mixture that supplies the specific minerals that are lacking. The formulas for various simple mineral mixtures which are well suited for swine are given in Chapter VI. (186)

If calcium is the only mineral that is lacking, there is no need of including in the mineral mixture bone meal or other supplements supplying phosphorus in addition to calcium. Merely such a cheap mixture as ground limestone and salt will be just as satisfactory. On the other hand, when there is a lack of both calcium and phosphorus, then a mineral mixture should obviously be used that supplies both of these nutrients.

The excellent results that have been secured in experiment station tests and on farms with simple mineral mixtures show definitely that there is no need of using more complex mineral mixtures containing such additional ingredients as sulfur, charcoal, coal, sodium carbonate, Glauber's salts, Epsom salts, etc.[56]

1406. Vitamin requirements.—Vitamin A and vitamin D are of great importance in swine feeding, as is shown in the following articles. Fortunately, swine that are on good pasture have their vitamin A requirements amply met through the high carotene content of green forage, and their vitamin D needs taken care of by the anti-rachitic effect of sunlight. In the case of swine not on pasture, the vitamin A and vitamin D requirements can be readily met by using field-cured legume hay as a vitamin supplement.

It is shown later that a supplement furnishing B-complex vitamins is not generally needed for swine fed balanced rations on good pasture. (1410) High-quality legume hay is the best substitute for pasture. Legume hay not only supplies carotene and vitamin D, but also B-complex vitamins, except vitamin B_{12}. (1383) It also furnishes certain unidentified vitamins or factors, which are essential for swine and which may be lacking in some dry-lot rations. (1415)

So far as is known, there is no deficiency of vitamin E in ordinary swine rations. Swine are able to synthesize ample vitamin C in their bodies and do not need a supply in their feed.

1407. Vitamin A and carotene.—Vitamin A is of great importance in pork production, because swine which are not on pasture may suffer seriously from a deficiency of it.[57] The effects of a lack of vitamin A have been discussed in Chapter VII. (192)

Feeds of plant origin owe any vita-

min A value they may have to carotene content, for they do not contain vitamin A. The vitamin A requirements of swine are therefore commonly stated in terms of carotene.

Swine on green pasture are abundantly supplied with carotene. On the other hand, a deficiency is apt to occur when they are fed only grain and other concentrates, unless the grain is yellow corn. As is emphasized later in this chapter, any lack of carotene can readily be prevented by including good-quality alfalfa or other legume hay in the rations of swine in dry lot.

When swine have an abundant supply of carotene, as they do on good pasture, they store considerable amounts of vitamin A in their liver and other tissues. Because of this store, brood sows and well-grown pigs that have been on good pasture in summer may not show any marked deficiency of vitamin A, even if fed for some time in winter a ration lacking in vitamin A value.

The special committee of the National Research Council, in their report mentioned previously, recommends 2.0 milligrams of carotene daily per 100 lbs. live weight for growing and fattening pigs.[2] For growing breeding stock and especially for lactating gilts and sows much more carotene is advised per 100 lbs. live weight. The author has mainly followed these recommendations in the feeding standards given in Appendix Table III.

In its report the committee has also stated the amounts of carotene recommended per pound of air-dry feed, as follows: For breeding stock, 2.5 milligrams per pound of feed; for 25-lb. pigs, 0.25 milligram per pound of feed; and increasing to 0.60 milligram per pound of feed for 250-lb. pigs. The amount of carotene per pound of feed is increased as the pigs grow larger, because they eat less feed per 100 lbs. live weight, and it is believed that the carotene needs are proportional to the live weight.

It is believed that these allowances provide a considerable margin of safety under usual conditions. Much smaller amounts of carotene have been sufficient in experiments with pigs and with brood sows, conducted to determine the minimum requirements.[58]

It has been explained previously that the measurement of vitamin A value in terms of International Units is based upon experiments with rats. (**194**) Swine are much less efficient than rats in utilizing carotene to meet their vitamin A needs. They therefore require about 2.5 times as many International Units of vitamin A value when it is furnished by carotene, as when it is supplied by vitamin A itself.[59]

Brood sows fed rations seriously deficient in vitamin A may fail to come in heat or may not conceive when bred. If they do become pregnant, the pigs are apt to be born dead or very weak.

If pigs are fed a ration that is satisfactory, except for a lack of vitamin A, they may make excellent gains at first and then die later from pneumonia, brought on by lack of the vitamin. Sometimes vitamin A deficiency in swine may be confused with rickets, which is caused by a lack of vitamin D or a deficiency of calcium or phosphorus.

In both cases pigs may become paralyzed so they cannot rise to their feet. In vitamin A deficiency the condition is caused by degeneration of the nervous system, resulting in lack of control of the legs, instead of inability to move them. In walking, the pigs have a peculiar jerky gait, in which the rear legs are thrown out to the side. One of the first symptoms of vitamin A deficiency is often marked restlessness. Later, the pigs may have severe spasms and also show characteristic impairment of vision.

1408. Vitamin D.—Before vitamin D was discovered, swine in this country often suffered severely from rickets when they were confined and had no access to sunlight. As stated in Chapter VII, the most characteristic symptom of rickets in pigs is stiffness of the legs, especially of the hind legs. In severe cases, the hind legs are often paralyzed, because of which condition the disease was sometimes called "posterior paralysis."[60]

When swine are allowed to run outdoors for a considerable part of the day,

where they are exposed to sunlight, the ultra-violet rays in the sunlight usually provide them with plenty of vitamin D, even in winter. (201) In Minnesota experiments, pigs suffering from rickets produced by a lack of vitamin D recovered to a marked extent when exposed to sunlight in winter for only 45 to 90 minutes a day.[61]

When the ration has an ample amount of calcium and phosphorus and also has a proper calcium-phosphorus ratio, swine require much less vitamin D than under other conditions. (152) Because of their rapid bone formation, pigs that are growing very fast require more vitamin D than those that are growing more slowly.

The various breeds of swine seem to differ remarkably in their vitamin D requirements. If they have plenty of calcium and phosphorus, white pigs, at least those of the Yorkshire and the Danish Landrace breeds, may not have any symptoms of vitamin D deficiency under conditions where black or red pigs would be seriously affected. This may be due partly to greater penetration of ultra-violet light into the tissues and a consequent greater storage of vitamin D by white pigs, during any period when they may have been exposed to sunlight.

In Canadian experiments Yorkshire pigs did not show any symptoms of vitamin D lack when confined indoors from weaning time and fed rations practically devoid of vitamin D, but supplying ample calcium and phosphorus.[62] Also, the skeletons of these pigs had a normal mineral content.

In the report of the special committee of the National Research Council, referred to previously, rations containing 90 International Units of vitamin D per pound of feed are advised for swine not exposed to sunlight.[2] The requirement for white breeds is apparently much less.

All common concentrates used for swine feeding are deficient in vitamin D. No appreciable amount is supplied by any of the grains or other seeds, by any of the common concentrates of plant origin, or by tankage, meat scrap, skimmilk, buttermilk, or whey. (204) Some fish meal may supply vitamin D, but it cannot be relied on as a source, unless the vitamin D content is known.

Unless pigs are closely confined and have no access to direct sunlight, an ample amount of vitamin D to prevent rickets even in winter is usually supplied when 5 per cent or more of good-quality field-cured alfalfa or other legume hay is included in the ration. The use of legume hay for this purpose is discussed in detail later in this chapter. (1417)

If pigs are closely confined, it may be advisable to add a vitamin D supplement, even when the ration contains 5 per cent of field-cured legume hay.[63] It should be borne in mind that although dehydrated legume hay is usually richer in carotene than field-cured hay, it generally has very little vitamin D. (204)

1409. Vitamin A or D supplements. —When good legume hay cannot be provided for pigs or brood sows kept in dry lot, a vitamin A or vitamin D supplement should be used.

Cod-liver oil or cod-liver-oil concentrate supplies both vitamin A and vitamin D. Including 0.50 to 1.00 per cent of cod-liver oil or 0.125 to 0.25 per cent of cod-liver-oil concentrate in a ration for pigs furnishes sufficient of these vitamins.[64] Irradiated yeast is an effective vitamin D supplement for swine, but does not furnish vitamin A. Synthetic vitamin A is an effective vitamin A supplement, but of course has no vitamin D value.

Sometimes the inclusion of 5 per cent of field-cured alfalfa hay in a winter ration does not supply quite enough vitamin D for pigs which do not have much exposure to sunlight. Experiments were therefore conducted during 4 winters at the New York (Cornell) Station to find whether there would be a benefit from adding cod-liver oil or cod-liver-oil concentrate to a good ration containing 5 per cent of alfalfa hay.[65] During favorable weather, the pigs had access to small outside paved lots for a few hours daily. However, in this area of New York there is an unusually large proportion of cloudy weather in winter. The pigs therefore had less exposure to ultra-violet light than

there would have been in a sunnier region. Even under these conditions, there was no benefit from an additional A-D supplement, and its use increased the cost of the gains appreciably.

In 7 other similar New York experiments with fall pigs fed in dry lot in winter, the use of cod-liver-oil concentrate as a vitamin supplement was compared with adding 5 per cent of ground field-cured alfalfa hay to the ration.[66] The gains were slightly more rapid and the feed cost per 100 lbs. gain appreciably lower on the ration containing alfalfa hay and no cod-liver-oil concentrate. During the 7 winters, only one pig fed this ration showed any symptoms of rickets. These were mild and the pig made excellent gains throughout the winter. Similar results were secured in 3 Ohio experiments.[67]

1410. B-complex vitamins.—Swine require certain of the B-complex vitamins and are dependent chiefly on the supply in their feed, thus differing from cattle or sheep. This is because there is only a very limited synthesis of these vitamins through bacterial action in the large intestine of swine, while sufficient amounts to meet the needs of ruminants are normally synthesized in the rumen. (208)

Fortunately, when swine are on satisfactory pasture, there are rarely deficiencies of B-complex vitamins. Also, sufficient good legume hay or alfalfa meal usually prevents a lack of these vitamins, except vitamin B_{12}.

The need of young pigs for several of the B-complex vitamins in the diet has been proved by feeding highly purified artificial rations. To prevent the pigs from securing vitamins synthesized in the feces, they were kept on wire screens, or the concrete floor was washed carefully each day.

In such experiments it has been proved that young pigs require thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, and perhaps folic acid. Biotin is also required, but it is synthesized in the body rapidly enough under practical conditions to meet the needs. Inositol and para-amino-benzoic acid do not seem to be needed. References to the reports of the numerous experiments proving the requirements for the B-complex vitamins are given in the report of the special committee of the National Research Council which has been mentioned previously.[2]

In this report the committee recommends that swine rations should have the following amounts of B-complex vitamins. The requirements for all the vitamins except vitamin B_{12} are stated in terms of milligrams per pound of air-dry feed. The requirements of vitamin B_{12} are stated in micrograms (mcg.). A microgram is one-one thousandth of a milligram, or one-one millionth of a gram.

B-vitamin requirements per pound of feed

	25-lb. pigs	50-lb. pigs	100-lbs. and over	Breeding stock
Thiamin, mg. . .	0.5	0.5	0.5	0.5
Riboflavin, mg.	1.2	1.0	1.0	1.2
Niacin, mg. . .	8.0	6.0	5.0	5.0
Pantothenic acid, mg. . . .	5.0	5.0	4.5	4.5
Pyridoxine, mg.	0.6	0.6	. . .	. . .
Choline, mg. . .	400.0	. . .	. . .	. . .
Vitamin B_{12}, mcg.	7.0	5.0	5.0	. . .

The effects of a deficiency of each of these B-complex vitamins are shown in detail in Chapter VII. Any ordinary ration for swine will furnish an abundance of thiamine and also plenty of pyridoxine. There is no lack of choline in most rations that are otherwise satisfactory. The other essential B-complex vitamins are discussed in the following articles.

It is of interest that the amount of thiamine in the lean of pork is considerably increased when pigs are fed a ration rich in thiamine.[68]

1411. Riboflavin.—Such a ration as corn, soybean oil meal, and minerals, with only 5 per cent of alfalfa meal is a trifle low in riboflavin for young pigs in dry lot. The lack can be corrected by increasing the alfalfa meal to 10 per cent; or by substituting meat scrap or fish meal for part of the soybean oil meal; or by

adding a small percentage of a feed rich in riboflavin, such as distillers dried solubles, dried whey, or brewers' dried yeast.

1412. Niacin.—An important fact in swine feeding is that corn and oats contain much less niacin than do barley, the grain sorghums, or wheat. According to average analyses, even when corn and oats are the only grains in a well-balanced ration, the niacin supply will be fully equal to the amounts stated in the previous table of requirements, except for very young pigs.

However, under practical conditions, young pigs in dry lot, fed chiefly on corn or corn and oats, sometimes suffer from diarrhea, or enteritis, because of a lack of niacin.[69] This may be due to variation in niacin content of various lots of grain.

Another reason why niacin deficiency is more apt to occur when corn is the only or the chief grain is that corn is very low in tryptophan. It has been shown in Chapter VII that niacin can be made in the body from tryptophan.[70] (213) Therefore a deficiency of tryptophan accentuates a lack of niacin.

Including alfalfa meal in a ration low in niacin and replacing part of the corn or oats with other grain will correct the deficiency. Also, the niacin supply can be still further increased by adding wheat middlings, meat scrap, tankage, dried distillers solubles, or dried brewers' yeast, all of which are high in niacin.

Such changes in the ration will not prevent or cure the kind of enteritis, or diarrhea, caused by infection and not by nutritive deficiency.[71]

1413. Pantothenic acid.—The most noticeable symptom in pigs of a lack of pantothenic acid is incoordinated, wobbly gait, commonly called "goose-stepping." A deficiency also causes lack of appetite and poor growth.

There may not be sufficient pantothenic acid in balanced rations for young pigs in dry lot, unless care is taken to include a sufficient amount of feeds having a good supply of the vitamin.[72] A deficiency rarely occurs on pasture.

Meat scrap, tankage, and fish meal are all low in pantothenic acid, and the content in the grains is only fair. Soybean oil meal, linseed meal, wheat middlings, and distillers dried solubles have considerably more, and peanut oil meal, dried buttermilk, dried skimmilk, dried whey, brewers' dried yeast, and cane molasses are rich sources.

A ration of grain, balanced only with meat scrap, tankage, or fish meal is apt to be low in pantothenic acid, even if it has as much as 10 per cent of alfalfa meal.

1414. Vitamin B_{12}.—As stated in Chapter VII, many experiments conducted some years ago proved that for pigs in dry lot a ration entirely from plant sources was generally improved by adding a feed of animal origin, such as tankage, meat scrap, fish meal, or dairy by-products. (**220**) The name *animal protein factor* was given to this quality of animal-source feeds.

After vitamin B_{12} was discovered a few years ago, it was found that much of the benefit from the addition of a feed of animal origin to a plant-product ration was due to the vitamin B_{12} it supplied. However, these animal-source feeds also furnish certain unidentified vitamins or factors that may be lacking in dry-lot rations for swine.

Though much less synthesis of vitamin B_{12} occurs through bacterial action in the digestive tract of swine than in the case of ruminants, there is a limited amount in the intestines. This seems to be the reason why in some experiments, when the ration had plenty of cobalt, there has been no appreciable benefit from adding a vitamin B_{12} supplement to a dry-lot ration for swine, which was low in the vitamin.[73] (Vitamin B_{12} contains a small amount of cobalt as an essential constituent.)

Feeds of animal origin, including meat scrap, tankage, fish meal, and dairy by-products are good sources of vitamin B_{12}. Condensed fish solubles and liver meal are especially rich in it, as is also sewage sludge. Feeds of plant origin apparently have little or none, according to the usual methods of analysis.

It is interesting and important that alfalfa hay or meal, even of excellent quality, furnishes only a trace of the

vitamin, as determined by microbiological methods of analysis. Yet swine on alfalfa or other good pasture show no evidence of vitamin B_{12} deficiency, even when fed a ration lacking in the vitamin.[74]

Either sufficient vitamin B_{12} must be synthesized in the intestines of pasture-fed pigs, or else they must secure the mere traces of the vitamin needed from insects and worms they consume.

The minute amount of vitamin B_{12} needed by young pigs in dry-lot is shown in the previous table of B-complex vitamin requirements. The amount of 7.0 micrograms per pound of feed is only 1 part of the vitamin to 64 million parts of feed—indeed a mere trace, though it is essential.

A lack of vitamin B_{12} is much more apt to occur with young pigs than with older ones. In rations that may be deficient in the vitamin it may readily be supplied by a commercial B_{12} feed supplement or by an antibiotic-vitamin B_{12} feed supplement.

1415. Unidentified vitamins or factors.—Swine, at least very young pigs, may require certain unidentified vitamins or factors when they are kept continuously on a screen floor or on concrete which is washed daily. Under such conditions they cannot get an appreciable amount of any such factors which may be synthesized by bacterial action in the feces.

The need of such vitamins or factors is indicated by the fact that it is difficult or impossible to secure maximum growth of baby pigs if they are fed a highly-purified ration containing no natural feed, even when all the known vitamins are supplied. In some experiments baby pigs, removed from the sow a few days after birth and fed such diets, have made better growth when there was added a concentrate of grass juice, or milk, or fish solubles, or certain fermentation residues from antibiotic manufacture.[75] However, in other studies there has been no benefit from such additions to a diet containing all known nutritive essentials.[76]

If young pigs do need unidentified vitamins, they are evidently supplied plentifully by good pasture.

1416. Feeding B-complex supplements.—Whether there will be a benefit from adding a B-complex vitamin supplement to a practical balanced ration for young pigs or older hogs will depend first of all on the nature of the ration. Also, there may be a benefit from such a supplement in the case of unthrifty pigs or pigs that have previously received a poor ration, while there may be no improvement with thrifty pigs, well-fed previously.

As is shown in the preceding discussions of the various B-complex vitamins, there is most apt to be an advantage from adding B-complex vitamins to such a ration as corn, soybean oil meal, minerals, 5 per cent alfalfa meal, and an antibiotic-B_{12} supplement. There is less likely to be a benefit from such an addition to a ration that has an animal protein supplement, or more alfalfa.

In an Indiana trial adding riboflavin, niacin, and pantothenic acid to a good dry-lot ration increased the gains of young pigs 10 per cent.[77] This ration consisted of yellow corn, soybean oil meal, cottonseed meal, fish meal, meat-and-bone scrap, alfalfa meal, a complete mineral supplement, a vitamin A-D supplement, and an antibiotic-vitamin B_{12} supplement. Similar results were secured in a Michigan experiment.[78]

On the other hand, in a Minnesota trial, the addition of the same vitamins to a similar ration produced no benefit, and in a Kansas trial no appreciable improvement.[79]

In Michigan trials young pigs suffering from severe diarrhea caused by inadequate rations were secured from several farms.[80] Most of them recovered when treated with B-complex vitamins and fed a good ration that supplied liberal amounts of vitamins.

Several experiments were conducted some years ago to determine the effect of supplementing rations for pigs with yeast (which is rich in all important B-complex vitamins except B_{12}). In some of the trials the yeast was added to the moistened feed several hours before it was fed, and fermentation allowed to

take place. No matter what method of yeast feeding was used, it was not profitable to add yeast to rations that included such protein supplements as tankage or meat scrap.[81] Generally the rate of gain was not improved and the cost of the gains was increased.

In Ohio experiments, however, there was an appreciable benefit when yeast was grown in a ration of corn, soybean oil meal, minerals, and 5 per cent of alfalfa.[82] Young pigs fed continuously in dry-lot on this ration, without yeast, often did not thrive.

In Wisconsin trials, young pigs fed in dry lot on corn, soybean oil meal, minerals, and only 5 per cent of alfalfa hay did much better when they had access to fresh cattle manure.[83] The benefit was undoubtedly due to the content of B-complex vitamins in the manure. Increasing the percentage of alfalfa hay in the ration to 15 per cent was fully as beneficial as letting the pigs have access to the manure.

In New York tests, adding cow manure to a plant-source ration for pigs in dry lot increased the gains less than did the addition of a trace mineral mixture.[84] The addition was of no benefit with a ration of corn and a trio-type supplemental mixture.

The amounts of the different B-complex vitamins in important feeds are shown in Appendix Tables V, Va, and Vb, so far as information is available. Where the natural feeds in a ration do not supply sufficient B-complex vitamins, a concentrated commercial B-complex supplement will correct the deficiencies.

1417. Legume hay is vitamin insurance.—When well-cured legume hay is available, any lack of vitamins, except vitamin B_{12}, can generally be prevented by including a sufficient amount of such hay in rations for swine not on pasture. This is particularly important for young pigs and for brood sows and boars. Vitamin B_{12} can readily be supplied by including a vitamin B_{12}-antibiotic feed supplement in the ration.

Field-cured legume hay of good quality not only supplies carotene and vitamin D, but it is also an excellent source of the B-complex vitamins, except B_{12}. In addition, it furnishes certain unidentified vitamins or factors that may be needed by swine kept continuously in dry lot. Other benefits from including legume hay are that it is rich in protein and calcium.

Alfalfa hay or alfalfa meal is used more often than other kinds of legume hay for swine. However, other legume hays are satisfactory substitutes for alfalfa, as is shown in the discussions concerning the various kinds of legume hay in Chapter XVI.

Dehydrated alfalfa or other dehydrated legume forage is even richer than field-cured hay in carotene and in B-complex vitamins. However, it generally has very little vitamin D, and therefore does not serve as a vitamin D supplement.

As is shown in the next chapter, brood sows will usually eat enough good-quality alfalfa hay when it is fed uncut in a rack. They are much less apt to eat a sufficient amount of red clover hay, sweet clover hay, soybean hay, or cowpea hay when thus fed.

Growing and fattening pigs often will not consume a sufficient amount of alfalfa or other legume hay for vitamin insurance when it is fed in a rack. The safest plan in feeding pigs not on pasture is therefore to include a definite proportion of high-quality legume hay mixed in the ration.

When young pigs get a good start on pasture before they are put in dry lot and when the ration contains some protein supplement of animal origin, there is generally no need to use more than about 5 per cent of legume hay in the ration. On the other hand, when such a combination is fed as corn supplemented by soybean oil meal and minerals, it is best to increase the proportion of legume hay to 10 or 15 per cent to prevent any vitamin deficiencies.

Experiments have shown that if pigs remain thrifty, they are apt to make slightly more rapid gains and to require less feed per 100 lbs. gain when the ration does not have more than about 5 per cent of legume hay.[85] The difference is especially marked if 15 per cent

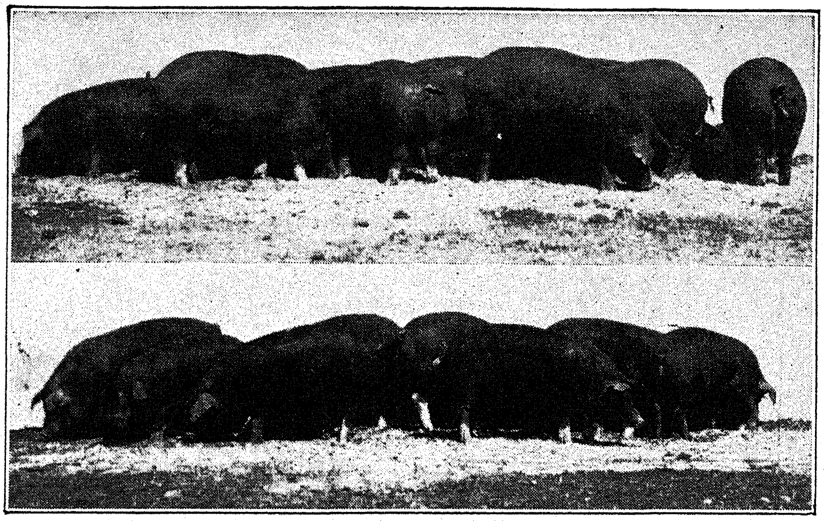
or more of hay is included in the ration.

The results from including a large proportion of high-quality alfalfa meal in the ration for growing and fattening pigs are discussed further in other portions of this chapter. (**1396, 1431**)

Rations for brood sows not on pasture had best contain at least 10 to 15 per cent of well-cured legume hay or else alfalfa meal as vitamin insurance. (**1459**)

provide a supply of vitamins. For these reasons, pigs may not suffer from vitamin deficiencies under farm conditions, although the feeds that they are regularly given would produce disaster if fed under controlled, experimental conditions.

1418. The trio mixtures.—Before the discovery of vitamin D in 1922 and at a time when little was known about the importance of vitamin A for swine,



TRIO MIXTURE EXCELLENT FOR DRY-LOT FEEDING

The trio mixture and similar protein supplements are superior to tankage, meat scrap, or fish meal as the supplement for pigs in dry lot. Pigs in the upper lot, fed yellow corn and the trio mixture, gained faster and were more thrifty than the pigs in the lower lot, which were fed yellow corn and tankage. (From Wisconsin Station.)

If pigs have been raised to a weight of 100 lbs. or more on good pasture, they may have a sufficient store of vitamins in their bodies to enable them to make satisfactory gains up to the usual market weights on a ration somewhat deficient in vitamins. However, even for such pigs it is best to include legume hay in dry-lot rations as a cheap insurance against vitamin deficiencies.

When pigs follow cattle in the barnyard and work over the manure, they undoubtedly secure abundant amounts of B-complex vitamins from the manure, and also more or less carotene and vitamin D. Also, kitchen garbage helps to

investigations were conducted at various experiment stations in an attempt to develop rations which would enable young fall pigs to thrive in dry lot like spring pigs did on good pasture. The author and associates at the Wisconsin Station first found that young pigs in dry lot were greatly benefited by adding good-quality alfalfa hay to such a ration as corn and tankage.[86]

Finally, the author and associates developed a combination of supplements which was decidedly superior to any common single protein supplement for young pigs not on pasture. This was a mixture of 50 lbs. tankage or meat scrap,

25 lbs. ground or chopped alfalfa hay or other legume hay, and 25 lbs. linseed meal.[87]

As is shown later, further experiments at the Wisconsin Station and at other stations have shown that various modifications are satisfactory in this mixture. (**1420**) Such supplemental mixtures are commonly called "trio mixtures."

As is stated later in this chapter, even such an efficient supplement as a trio mixture is generally improved for pigs in dry lot by adding an antibiotic-vitamin B_{12} supplement. (**1422**)

The advantage from using the trio mixture or a similar combination for pigs not on pasture is clearly shown by the results of 31 experiments in each of which one lot of pigs was fed yellow corn and the original trio mixture, while another lot received yellow corn and tankage.[88] The pigs fed the trio mixture gained 1.28 lbs. per head daily until they reached market weights, while those fed corn and tankage gained 1.10 lbs. per day. On the trio mixture an average of 351 lbs. corn and 63 lbs. trio mixture was required per 100 lbs. gain, while on tankage as the only supplement there were required 384 lbs. corn and 44 lbs. tankage. In these experiments each 100 lbs. of the trio mixture saved 70 lbs. tankage and 52 lbs. corn.

The most important advantage of the trio mixture over tankage for pigs not on pasture is not the slight increase in rate of gain or the slight saving in feed required for 100 lbs. gain. The chief merit of the trio mixture and similar combinations is the insurance against some of the pigs becoming unthrifty or even runts, because of a lack of vitamins. It is fortunate, indeed, that this insurance can be gained, not only without added expense, but at an actual saving in cost.

The advantages secured from a trio mixture can mostly be gained by adding merely alfalfa hay to such a ration as grain and tankage. However, experiments have shown that the gains are slightly more rapid and also more economical when corn and such a mixture are fed to young pigs in dry lot, instead of a ration of corn, tankage, and alfalfa hay.[89]

If pigs are well grown on pasture or on grain and such a supplement as a trio mixture until they reach a weight of 100 lbs., they can usually be fed safely on only grain and tankage or meat scrap until they reach the usual market weights. Sometimes the cost of gains may even be a trifle less, after this time, than on yellow corn and the trio mixture.[90] However, it is the safest plan to continue to use the trio mixture or a similar combination until the pigs are marketed, especially in the case of fall pigs fed in dry lot during winter conditions in the northern states. The trio mixtures and similar combinations are satisfactory for feeding to pigs on pasture, but if the pasture is really good, there is no need of including legume hay in the combination of supplements.

1419. Methods of feeding trio-type mixtures.—The trio mixtures and similar supplemental combinations produce excellent results when self-fed, free-choice, as the supplement to shelled corn, also self-fed, or to ear corn that is full-fed. In 3 Wisconsin tests the gains were about as rapid and were slightly more economical when pigs were thus self-fed, free-choice, on shelled corn and the trio mixture, than when a mixture was self-fed which consisted of ground corn and the proper proportion of the trio mixture to balance the ration.[91]

When pigs are fed the grains that are richer in protein than corn (including barley, oats, kafir, and rye) they may eat a larger amount than needed of the trio mixture or similar mixtures, if the mixture is self-fed, free-choice. With such grains, except in the case of wheat, it is generally more economical to mix the proper proportion of supplement with the ground grain and then self-feed the mixture.

1420. Other supplemental mixtures for dry lot.—Many experiments have been conducted by the experiment stations in this country to compare different combinations of protein supplements for pigs fed in dry lot and for those on pasture. Only the briefest summary can be presented here of certain of the most important results of these studies. Some of the conclusions from these experiments

are also given in the detailed information concerning the various protein supplements in Chapters XX to XXIII.

Several supplemental mixtures suitable for feeding, free choice, as the supplement to corn or other grain for pigs in dry lot are given in Appendix Table VII.

To provide insurance against vitamin deficiencies, 25 per cent of alfalfa or other legume hay was included in the original trio mixtures. When such a mixture is self-fed, free-choice, with corn to pigs in dry lot, the legume hay will generally form only about 3 per cent of the total ration. This small proportion is usually sufficient to produce excellent results with the trio mixtures, which contain 50 per cent of tankage, meat scrap, or fish meal. The experiments reviewed previously in this chapter show that a larger proportion of legume hay is often needed to prevent vitamin deficiencies when the ration contains no protein supplement of animal origin.

Supplemental mixtures containing only 10 per cent of legume hay or leaf meal produce very satisfactory results when the pigs are well started on pasture before being confined to dry lot, especially if the mixture contains some fish meal. Thus, in experiments by Vestal at the Indiana Station, the supplemental mixture that ranked first (Purdue Mixture No. 5) was a combination of 20 per cent fish meal, 20 per cent meat-and-bone scrap, 40 per cent soybean oil meal, 10 per cent cottonseed meal, and 10 per cent alfalfa leaf meal.[92] It was found that the fish meal in the mixture could be decreased to 10 per cent, with an increase in the meat-and-bone scrap to 30 per cent, without decreasing the efficiency appreciably.

Soybean oil meal is fully equal to linseed meal when used instead of linseed meal in a trio mixture.[93] Dried distillers solubles is also a good substitute for linseed meal in such mixtures. (**955**) Cottonseed meal can be used in place of linseed meal in such mixtures, but does not usually produce quite as good results. (**918**) Neither wheat standard middlings nor corn germ meal are as good as linseed meal or cottonseed meal in these mixtures.[94] Ground raw soybeans are still less satisfactory.[95]

Fish meal is even superior to tankage or meat scrap in trio mixtures. (**919**)

When meat scrap, tankage, and fish meal are scarce or unusually high in price, the proportion of this kind of feed in the supplemental mixture can be reduced considerably without greatly decreasing the efficiency, if soybean oil meal is used as the substitute. Calcium and phosphorus supplements should then be included in the mixture. For example, a supplemental mixture recommended under conditions in World War II was: 10 per cent of tankage or meat scrap, 40 per cent soybean oil meal, 19 per cent linseed meal, peanut oil meal, or cottonseed meal, 25 per cent alfalfa hay, 3 per cent ground limestone, 1 per cent bone meal, and 2 per cent salt.[96]

Recent experiments have shown that when an all-plant-source ration of corn and soybean oil meal is completely supplemented with minerals, vitamins, and an antibiotic-vitamin B_{12} supplement, growing and fattening pigs in dry lot may make as rapid and efficient gains as when meat scrap or tankage is added.[97] However, for dry-lot feeding an all-plant-source ration requires very careful supplementation to equal a ration that includes a protein supplement of animal origin.

For self-feeding, free-choice, as the supplement to corn or other grain, supplemental mixtures which contain at least 35 per cent of protein are most efficient.[98]

1421. Supplemental mixtures for pasture feeding.—For pigs on good pasture, there is much less difference than for pigs in dry lot between the results from feeding tankage or meat scrap as the only protein supplement and the results from efficient combinations of supplements. This is largely because ample amounts of all the vitamins are supplied by pasture combined with the sunlight pigs get on pasture. Also, good pasture helps to meet the needs for both amount and quality of protein, and it aids in supplying calcium and phosphorus.

However, in numerous experiments with pigs on pasture there has generally been some advantage in using a com-

bination of tankage or meat scrap with soybean oil meal, cottonseed meal, linseed meal, or peanut oil meal, instead of feeding tankage or meat scrap as the only supplement. With such a combination, the gains have usually been slightly more rapid and a little less feed has been required per 100 lbs. gain. Using a mixture of this kind also greatly reduces the necessary amount of tankage or meat scrap, of which there may be a rather scanty supply.

Pigs on pasture will generally make as rapid gains when fish meal is the only supplement to corn or other grain, as when a combination is used of fish meal with cottonseed meal, soybean oil meal, or linseed meal.[99] Whether or not it will be more economical to feed such a combination will depend on the relative prices of fish meal and the other supplements.

A combination of soybean oil meal with tankage, meat scrap, or fish meal is an excellent supplement to corn or other grain for pigs on pasture.[100] In New York experiments in which pigs on pasture were self-fed mixtures of ground corn and various protein supplemental combinations, 3 parts of soybean oil meal to 1 of meat scrap was slightly superior to equal parts of these feeds or equal parts of linseed meal and meat scrap.[101]

Soybean oil meal is liked so well by swine that when a supplemental mixture which consists largely of soybean oil meal is self-fed, free-choice, they may eat more of the supplement than they need. This can be prevented by mixing ground alfalfa hay or mineral mixture in the supplement. (**805**)

Combinations of cottonseed meal with tankage, meat scrap, or fish meal are excellent for pigs on pasture. This is shown by the numerous experiments summarized in Chapter XXII. (**818**) For pigs on pasture, a mixture of one-half linseed meal and one-half tankage or meat scrap is usually a little superior to tankage or meat scrap as the only supplement.[102] However, this combination is slightly excelled by combinations including soybean oil meal.

Kentucky experiments show that a combination of soybean oil meal and dried corn distillers solubles is an excellent protein supplement for pigs on pasture.[103]

The trio mixture and similar combinations that include legume hay are satisfactory for feeding to pigs on pasture, but if the pasture is really good, there is no need for having legume hay in the supplemental mixture as vitamin insurance.

In Indiana experiments, Purdue Supplement C ranked first in rate of gain for self-feeding, free-choice, with corn to pigs on pasture.[92] This mixture is the same as Purdue Supplement 5 for dry lot feeding which has been mentioned previously, except that it contains 10 per cent of linseed meal in place of 10 per cent of alfalfa leaf meal. The average gain was slightly more rapid on this mixture than on a simple mixture of one-half soybean oil meal and one-half meat-and-bone scrap. However, there was no appreciable difference in the amount of feed required per 100 lbs. gain, or in the cost of the gains. In 2 tests Supplement 5, which included 10 per cent of alfalfa leaf meal, was as satisfactory as Supplement C for pasture feeding.

1422. Antibiotic supplements for pigs.—During the past few years literally hundreds of experiments have been conducted to determine the effects of adding an antibiotic feed supplement or a pure antibiotic to swine rations.[104]

As has been pointed out in the general discussion of antibiotic feed supplements in Chapter XXIII, most of the antibiotic supplements on the market supply not only an antibiotic or a mixture of antibiotics, but also vitamin B_{12}. (**966**) Such a supplement is called an antibiotic-vitamin B_{12} feed supplement. The effect of this kind of supplement may obviously be due both to the antibiotic and also to vitamin B_{12}.

Most of the antibiotic-feeding experiments have been with growing and fattening pigs. A few have been with pigs before weaning or pigs taken from the sows a few days after birth and fed a milk substitute. Some have been with

brood sows through pregnancy and lactation.

In the greatest number of trials, aureomycin (chlortetracycline) has been tested, but several experiments have been conducted with terramycin (oxytetracycline), penicillin, bacitracin, and streptomycin. Very little information is available concerning the effects of other antibiotics in swine feeding.

An effective level of antibiotic is 5 milligrams per pound of total ration, or 10 grams per ton.[2] For a protein supplemental mixture to be fed with grain, about 25 milligrams per pound of the supplement, or 50 grams per ton is recommended.

In a recent survey of the results of the experiments on antibiotic supplements for swine, Braude, Wallace, and Cunha found that under normal conditions of health, adding an aureomycin or terramycin supplement to rations for growing and fattening pigs increased the gain about 15 per cent, and reduced the amount of feed required per 100 lbs. gain by 2 to 5 per cent.[104] Terramycin has apparently not been quite so effective as aureomycin in the majority of such comparisons. In this survey they report that penicillin, streptomycin, and bacitracin have been somewhat less beneficial than aureomycin or terramycin, increasing the average gain about 10 per cent.

In 227 trials in which aureomycin, terramycin, penicillin, or streptomycin were added to rations, the rate of gain was not increased in 20 tests, and the feed efficiency was not improved in 45 comparisons.

In a few experiments a mixture of antibiotic supplements has been compared with single antibiotic supplements.[105] The results have differed, and at present there are insufficient data to conclude that such a mixture is more effective than aureomycin or terramycin as the single antibiotic supplement.[2]

In the case of unthrifty or runt pigs and pigs fed poor rations, an antibiotic-vitamin B_{12} supplement usually is much more beneficial than with thrifty pigs fed good rations. However, such a supplement is no substitute for efficient rations and careful sanitation.

The improvement from an antibiotic-vitamin B_{12} supplement is generally greater with an all-plant-source ration than with a ration containing a protein supplement of animal origin. In most of the experiments with pigs on good pasture, an antibiotic supplement has increased the gain, but often the increase has been less than in dry-lot trials.[106] In some of the pasture tests the antibiotic supplement has not reduced the amount of feed required per 100 lbs. gain enough to cover the cost of the antibiotic.

The greatest increase in rate of gain from an antibiotic supplement occurs during early growth. However, there is usually some benefit after pigs reach a weight of 100 to 125 lbs. Experiments have proved that the rate of gain from weaning to market weights is generally more rapid and the feed efficiency higher, when the antibiotic supplement is fed continuously until the pigs are ready for market.[107]

Opinions differ as to whether or not the requirement for protein is reduced by an antibiotic supplement.[108] In some tests there has seemed to be a protein-sparing effect, but in fully as many trials there was no such result.

An antibiotic supplement may slightly increase the proportion of fat in the carcass. However, if antibiotic-supplemented pigs are marketed at the same weight as those not fed an antibiotic supplement, there will be no significant difference in the depth of back fat, or in the proportions of fat and lean in the carcasses.[109] Nevertheless, for the production of high-quality bacon carcasses, it may be undesirable to continue the antibiotic supplement during the finishing period.[110]

The implanting of an antibiotic pellet under the skin of an ear of baby pigs has been suggested, as a means of administering the antibiotic before the pigs eat much solid food. However, in most of the tests, such implantation of an antibiotic has not been beneficial.[111]

In Minnesota trials, adding an aureomycin or terramycin supplement to the

creep feed for suckling pigs increased the gains.[112] Penicillin was less effective, and bacitracin did not improve growth. In trials by the United States Department of Agriculture, adding an aureomycin-vitamin B_{12} supplement to the creep feed increased the gains of suckling pigs.[113]

If pigs are removed from the sows at only a few days of age and fed a milk substitute, an antibiotic-vitamin B_{12} supplement should be included in the mixture. This will reduce scouring and mortality, as well as increase growth.[114]

1423. Antibiotic supplements for sows.—Several experiments have been conducted recently to find whether or not there was a benefit from adding an antibiotic supplement to a good ration for brood sows during gestation and lactation.[115] In most of the trials such a supplement has not been beneficial.

If an antibiotic supplement is included in a ration for sows suckling pigs, the pigs may eat some of the sow feed, and the weaning weight of the pigs be thus increased. No appreciable amount of antibiotic from the sow's feed is transferred into her milk.

1424. Arsonic supplements; surfactants.—Several experiments have been carried on recently to find whether there was an improvement from adding a small amount of arsonic acid or some other organic arsenic compound to rations for pigs.[116] (**967**) In the majority of the trials these supplements have been ineffective, or less beneficial than an antibiotic.

In cases where pigs are affected with bloody dysentery, an arsenical supplement aids in controlling the disease.

In most of the experiments in which a surfactant, or surface-active-agent, has been added to a ration for pigs, either the surfactant has not been beneficial, or else it has caused less improvement than an antibiotic supplement.[117] (**967**)

1425. Hormones.—Differing from the results with fattening cattle, adding stilbestrol (diethylstilbestrol) to rations for growing and fattening pigs has not increased the gains or feed efficiency.[118] (**1183**) Also, intra-muscular or subcutaneous injection of other sex hormones has little or no effect on gains.[119]

Experiments have been conducted to find whether the growth of pigs could be increased by adding thyroprotein to the ration. (**54**) In other trials the effect has been studied of adding thiouracil or thiourea to the rations of well-grown pigs during the later stages of fattening. The latter drugs suppress the secretion of thyroxine by the thyroid gland, and hence slow up body metabolism. They are called goitrogens, because they cause enlargement of the thyroid.

With reference to the use of thyroprotein in swine feeding, the committee on hormones of the National Research Council states, "The most successful use of thyroprotein has been obtained with young growing pigs, but even in young swine the results have been variable, and the effects of several factors that may influence results are not well defined." [120]

Concerning the addition of thiouracil or thiourea to rations for pigs, the committee states, "The use of goitrogens in swine husbandry must be considered to be still in the experimental stage. Whether or not the goitrogens presently available, used in such ways as have been tried to date, are suitable for use in pork production is a question that has not received a final answer.

"However, some goitrogens have produced significant increases in efficiency of utilization of feed without markedly decreasing rates of gain when they have been employed during the last 4 weeks of the fattening period. Administration of goitrogens for more than 6 weeks has depressed growth rates significantly.

"The possible danger to consumers of pork and pork products from retention of thiouracil is recognized, but this danger is negligible if goitrogen feeding is avoided during the last 3 days prior to slaughter."

1426. Water.—Swine should always be supplied with plenty of water. The amount of water consumed by pigs ranges from about 12 lbs. daily per 100 lbs. of animal at weaning time down to 4

lbs. or less per 100 lbs. live weight during the fattening period.[121] More water is of course needed in hot weather than in winter.

The amount of water consumed per head daily by brood sows was 7.5 lbs. in an Iowa test with pregnant yearling sows and 43 lbs. in an English test with brood sows suckling litters.[122]

Watering swine by means of an automatic waterer not only saves labor, but also insures a plentiful supply at all times. However, pigs given plenty of water in a trough two or three times a day apparently make as rapid and economical gains as those watered by means of an automatic waterer.[123]

In very cold winter weather, swine watered in a trough may not drink enough for the best results unless the water is warmed enough to keep it from freezing soon after it is put in the trough. In winter there is no need of warming water in an automatic waterer more than enough to keep it from freezing.[124]

Growing and fattening pigs self-fed on pasture graze the various parts of the pasture more uniformly if the water supply is not close to the self-feeder. However, South Dakota results indicate that in hot weather the water should not be more than about 300 feet from the self-feeder.[125]

III. General Problems in Pork Production

1427. Prices of hogs during the year.—In deciding upon the best plan of pork production to follow, one should consider the average prices of hogs on his own market for various months in the year. By having pigs ready for market at the time when the price is usually highest, the profit can commonly be increased decidedly.

The number of pigs farrowed in the spring in this country is much greater than of those born in the fall, and the bulk of these spring-farrowed pigs reach the market from late October to February. During this period the supply of hogs on the central markets is therefore the heaviest, and as a result the price is considerably lower than during the rest of the year.

If not artificially controlled, the average prices of hogs in the markets of this country are highest in August and September, when the receipts of hogs are lowest.[126] In October the average price begins to drop sharply, as the spring-farrowed pigs start to come to market in large numbers. The average price reaches the lowest levels from November through January, when the marketings are heaviest. The price then begins to recover and usually reaches a lower secondary peak in March. In April and May the price generally recedes somewhat, when the bulk of the fall pig crop comes to market. Then in June the rise begins to the August–September peak.

The farmer who has facilities for taking proper care of early spring litters can usually secure the highest price by having them ready for market before October. This means, however, that the pigs must be liberally fed on efficient rations and must have the best of care, or they will not reach a market weight of 200 lbs. or more by that time. Instead, they will get to market in November or December, when prices are low.

It is shown in the next chapter that farmers who raise early spring litters for marketing before the slump in price occurs in the fall, usually find it profitable to breed as many sows as possible for fall litters, as well. These are ready for market in spring, when prices have recovered.

1428. Limited-feeding vs. full-feeding of pigs.—One of the most important questions that every hog raiser must decide is how much grain he will feed his growing, fattening pigs. He knows that the larger the amount of grain or other concentrates he feeds, the faster they will gain, no matter whether in dry lot or on pasture, but he wonders whether or not he will make more profit if he restricts the amount of concentrates.

It has been shown previously that animals fed liberal rations tend to digest and utilize their feed with slightly less efficiency than those that receive limited

rations. (101) However, if a growing and fattening animal, such as a pig, is fed a limited ration, a longer time will be required before it reaches the desired market weight and the proper degree of fatness. This will increase the amount of feed required for mere body maintenance during the growing and fattening period, and therefore reduce the proportion of feed available for producing gain in weight.

These two factors therefore tend to have an opposite effect on the relative amounts of feed required per 100 lbs. gain by pigs that are full-fed and by those that are fed limited rations. The net effect of limited feeding can be determined only by experiments in which pigs are full-fed in direct comparison with others that receive limited amounts of the same feeds. It is important that such tests be continued until the limited-fed pigs have reached market weights, which has not been done in some of the experiments on this problem.

1429. Effect of feeding level on the carcass.—The experiments of Hammond and McMeekan, summarized in Chapter IX, showed that the proportions of lean and fat in hog carcasses could be changed appreciably by methods of feeding. (283) By feeding a liberal ration until pigs were well grown, and then limiting the feed intake during the finishing period, a larger proportion of lean and less fat was produced than when pigs were full-fed continuously.

The restriction in nutrient intake can be made either by feeding a reduced amount of an ordinary ration, or else by including in a full-fed ration a suitable amount of a very bulky feed, such as ground alfalfa or other hay. Ground corn cobs can be used similarly, but they merely dilute the ration and do not furnish much digestible nutrients to pigs.

The increase in the proportion of lean in the carcass is desirable, from the standpoint of our present market demand for leaner pork. However, this advantage may be offset by the fact that pigs which have had their net energy supply restricted will commonly yield an appreciably lower percentage of dressed carcass.

Where high-quality bacon carcasses command a considerable premium, as in Canada, it is generally most profitable to produce pigs that meet these requirements. On the other hand, on most of the United States markets such pigs do not bring a sufficient premium at present to warrant much additional expense in producing them.

1430. Limited feeding in dry lot.—Experiments have been conducted recently by the Minnesota and Missouri Stations to compare full-feeding continuously with the method of full-feeding until the pigs reached a weight of 125 lbs., and then feeding them only 75 to 85 per cent of a full ration.[127] In each experiment another group was fed the limited ration throughout the trials.

In 3 experiments the pigs fed liberally until they reached market weights gained an average of 1.46 lbs. a day and required 395 lbs. of feed per 100 lbs. gain. Those fed liberally at first and then fed the restricted ration during the finishing period gained 1.34 lbs. a day, and they needed 9 days longer to reach the same market weight. However, they required no more feed per 100 lbs. gain.

The pigs fed the limited rations continuously gained only 1.13 lbs. a day and it took 41 days longer for them to reach market weight than for the full-fed pigs. In spite of this, they needed slightly less feed per 100 lbs. gain than the other lots.

Such moderate restriction of feed during the finishing period produces desirable leaner carcasses, but the dressing percentage is usually about 2 per cent less than for full-fed pigs. In some cases the lower dressing percentage fully offsets the higher value of the leaner carcasses.

If the amount of feed for pigs in dry lot is still further reduced, the gains will be poor, and much more feed will be needed per 100 lbs. gain. This is because the pigs then need most of their feed for maintaining their bodies.

For example, in 2 New York tests pigs fed only a half ration from an aver-

age weight of 62 lbs. until they reached market weights gained only 0.65 lb. a day and required 428 lbs. of feed per 100 lbs. gain.[128] Others full-fed the same well-balanced feed mixture gained 1.39 lbs. and required only 391 lbs. of feed per 100 lbs. gain. Such scanty feeding therefore not only wasted feed but also doubled the amount of labor.

In addition, if the feed is restricted too much, the pigs will not be sufficiently fat at the usual market weights to yield high-quality carcasses.

It is sometimes advocated that to save grain, pigs in dry lot should be fed a decidedly limited ration until they reach a weight of 100 to 150 lbs. and then be full-fed until they are ready for market. However, this method is usually uneconomical, in comparison with continuous full-feeding or with full-feeding at first and finishing the pigs on a moderately limited amount of feed.[129]

If one is raising fall pigs to follow fattening cattle, it may be desirable to limit their feed slightly. Also, some farmers feed fall pigs a limited amount of concentrates during the winter, and then finish them on pasture in the spring. Ohio tests indicate that this is doubtful economy, unless grain is very high in price in comparison with the cost of pasture.[130] Too often such fall pigs are fed so little during the winter that their gains are exceedingly expensive and they may even become unthrifty because of stingy feeding.

1431. Restricting nutrients by adding roughage.—It has been mentioned that when it is desired to produce leaner carcasses, the nutrient intake during the finishing period may be reduced by including very bulky feed in the mixture and then self-feeding it. In a Wisconsin trial economical gains were made and good carcasses were produced when 28 per cent of ground low-grade alfalfa hay or 16 per cent of ground corn cobs was included in a self-fed mixture.[131] A larger proportion of the bulky feeds increased the cost of the gains, and the carcasses were not firm and graded lower.

In an Oklahoma experiment the nutrient intake was reduced after the pigs reached 140 lbs. in weight by adding 20 per cent of ground prairie hay to a self-fed mixture.[132] The pigs finished on the low-energy ration gained 0.23 lb. a day less than others self-fed the usual ration and required 76 lbs. more feed per 100 lbs. gain. They did not like the prairie hay mixture and wasted considerable feed around the self-feeders.

When one wishes to limit the nutrient intake on a self-fed mixture, it would seem preferable not to add a low-grade feed, but instead to include enough good-quality ground legume hay to have the desired effect.

1432. Limited-feeding on pasture.—Full-feeding pigs on pasture is generally much more profitable than limited-feeding, if the pigs are farrowed early enough in the spring so they can be fattened for marketing early in the fall, before the usual slump in price occurs.

With late spring pigs, the profit may be greater if they are fed only enough concentrates to keep them growing well during the summer and if they are then fattened on the new corn crop in the fall and early winter for marketing in January or February, after the price recovers somewhat. Pigs to be used in the fall for hogging-down corn or for following fattening cattle should also be fed a limited amount of grain in the summer, so they will be in thrifty feeder condition.[133]

Many trials have been conducted to compare full-feeding of pigs on good pasture throughout the season with feeding only a limited amount of grain during the pasture season, and then finishing them in the fall by full-feeding. In 32 such experiments pigs averaging 58 lbs. in weight at the start were fed to market weights on good pasture.[134] Those which were full-fed (usually self-fed) all the time gained an average of 1.45 lbs. a day and consumed 369 lbs. of concentrates per 100 lbs. gain. Pigs fed a limited amount of concentrates until fall and then finished by full-feeding gained 1.14 lbs. a day and needed 31 days longer to reach approximately the same market weight. These pigs, however, required a trifle less concentrates

(7 lbs.) per 100 lbs. gain, but they undoubtedly ate more pasturage. These data show clearly that under conditions in the corn belt it will commonly be most profitable to full-feed early spring pigs on pasture, so that they can be sent to market before the price declines severely.

This is also proved by a study of the net returns from early-spring litters on 43 Indiana farms where the pigs were fed limited amounts of grain during the first 3 months after weaning and on 24 farms where the full-feeding method was used.[135] The full-fed pigs were ready for market on September 27, on the average, and sold for 97 cents more per hundredweight than the limited-fed pigs, which were not ready for market until December 10. For each 100 lbs. gain the full-fed pigs required only 6.1 bushels corn and 8.2 lbs. tankage, while the limited-fed pigs needed 8.7 bushels corn and 6.6 lbs. tankage. The death loss after weaning was also in favor of the full-fed pigs, being only 2.5 per cent, in comparison with 7.5 per cent for the other pigs.

The total cost of 100 lbs. gain, including not only feed cost but also all other expenses, was 15 per cent less for the full-fed pigs, and the profit was therefore much greater.

For late spring pigs on good pasture or in the southern states for fall pigs, it may be desirable to limit the amount of concentrates somewhat, as the longer time needed to reach market weight may then be an advantage. Late spring pigs or fall pigs fed on good pasture may be ready for market after the bulk of the spring and fall pigs have been sold and thus bring a good price. Limited feeding, especially during the finishing period, will also produce leaner carcasses.

In Tennessee experiments pigs fed 80 or 60 per cent of full feed on good pasture made considerably cheaper gains than those which were full-fed.[136] Those fed the 80 per cent ration yielded high-quality carcasses, but the dressing percentage was 1.7 per cent less than for the full-fed pigs. The carcasses of the pigs fed the more limited ration lacked somewhat in finish.

In the alfalfa districts of the West it is often most profitable to limit the allowance of grain for pigs during the summer, for pasture is very cheap in comparison with grain.[137] This method is commonly used in the sections that specialize in the production of feeder pigs for shipment to the corn belt. Even when the pasture is excellent, it is necessary to feed 1.0 to 1.5 lbs. of grain per head daily to growing pigs, in order to keep them growing thriftily and making the desired gain in weight. Whether or not to feed a protein supplement to pigs receiving a limited amount of grain on first-class pasture has been discussed earlier in this chapter. (**1393**)

1433. Self-feeding.—Numerous experiments have proved that the feeding of fattening pigs by means of a self-feeder is efficient and economical. Pigs that are self-fed suitable rations not only make slightly more rapid gains than those that are hand-fed two or three times a day all they will eat, but also they usually require slightly less feed per 100 lbs. gain. In addition, considerable labor is saved.

Self-feeding is not only an excellent method of full-feeding fattening pigs or fattening sows, but it is also a good way to feed brood sows and their litters. It is not a satisfactory method of feeding pregnant sows, unless considerable bulky feed is included in the mixture that is self-fed. Even then, care is needed to keep the feeds so proportioned that the sows do not gain too much or too little. Therefore, hand-feeding pregnant sows is a much more common practice than self-feeding. (**1466**)

In self-feeding swine, grain and protein-rich supplements may be fed, free-choice, in separate compartments of the self-feeder, or the pigs may be self-fed a properly balanced mixture of grain and protein-rich supplements. The merits of these two methods have been discussed previously. (**1391**)

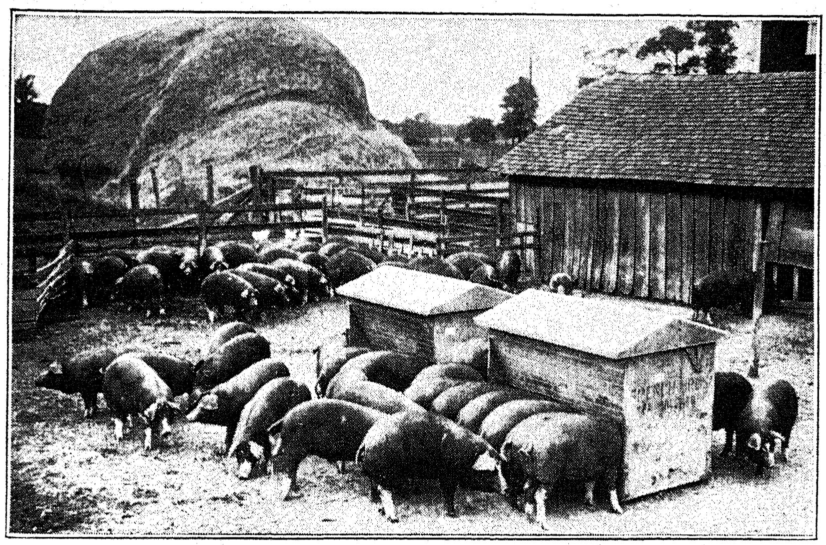
Although self-feeders are labor savers, they need daily inspection to make sure that none has become clogged or is out of adjustment so that feed is being wasted. If grain and a protein

supplement are being self-fed, free-choice, supplies of both should be available to the hogs at all times.

1434. Self-feeding vs. hand-feeding.—The excellent results secured when a self-feeder is used for fattening pigs are shown by 24 tests, in each of which one lot of pigs, not on pasture, was self-fed, free-choice, on such a ration as corn and protein supplement.[138] In each test another lot was hand-fed a well-balanced ration of the same feeds.

The self-fed pigs ate 0.6 lb. more corn per head daily than those which were hand-fed twice daily all they would clean up. This is the usual result and is due to the fact that self-fed pigs help themselves many times a day and even during the night, thus being "full-fed" at all times. Naturally, they gained a trifle more rapidly than those which were hand-fed, the average daily gain being 1.59 lbs. for the self-fed pigs and 1.42 lbs. for those which were hand-fed. Most important of all, is the fact that 11 lbs. less concentrates were required for 100 lbs. gain by the self-fed pigs. This is not a large saving in itself, but to it are added the advantages of the more rapid gains and the saving of labor by self-feeding.

That self-feeding is also an economical method of feeding pigs on pasture has been well proved. For example, in 9 trials pigs self-fed corn and tankage, free-choice on good pasture, gained 1.32 lbs., compared with 1.20 lbs. for others hand-fed the same feeds.[139] On the average the self-fed pigs ate 4 lbs. more tankage per 100 lbs. gain, but took 1 lb. less corn. This slight difference of 3 lbs. total feed per 100 lbs. gain in favor of the hand-fed pigs would, however, ordinarily be more than offset by the saving in labor through self-feeding and by the greater rapidity of the gains.



SELF-FEEDING IS EFFICIENT AND ECONOMICAL

Pigs self-fed in dry lot gain more rapidly than those which are hand-fed and require a trifle less feed per 100 lbs. gain.

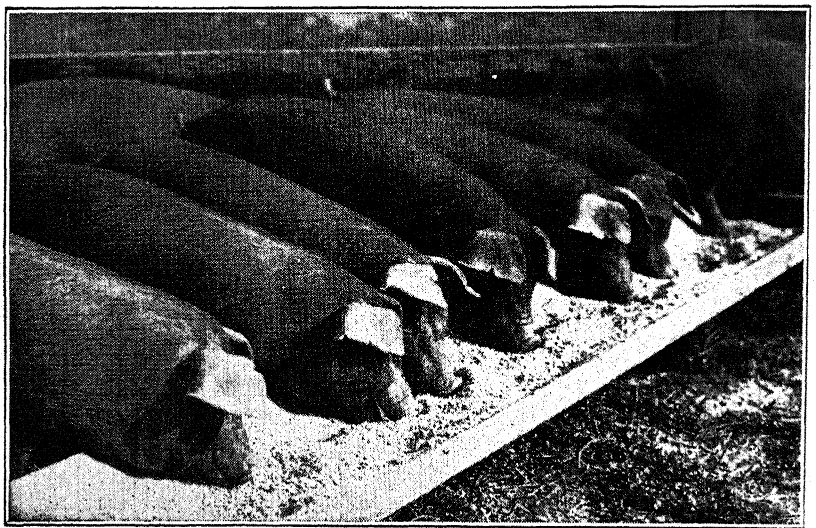
1435. Grinding grain for swine.—Whether or not it will pay to grind any particular kind of grain for swine depends on the completeness with which they chew it when unground. Definite information on this question is given for each kind of grain in Chapters XX and XXI.

In general, it does not pay to grind corn for pigs up to the usual market weights, or for brood sows. Instead, ear

corn or shelled corn is commonly fed. There is generally enough saving through grinding barley, oats, or millet to make such preparation decidedly profitable. If wheat and the grain sorghums are fed in self-feeders, pigs usually chew the grain with sufficient thoroughness so that grinding does not pay. On the other hand, when these grains are hand-fed, there is considerably greater saving through grinding.

When a finely ground mixture is fed outdoors in a windy location, slop-feeding may be advisable, merely to prevent feed being blown from the trough and wasted. Also, in very cold weather it may be advisable to feed a warm slop, so the hogs will get enough water.

With the exception of a few feeds, cooking feed for swine decreases its value, instead of increasing it.[142] Potatoes, soybeans, field beans, and velvet beans are greatly improved by cooking.



HAND-FEEDING REQUIRES MORE LABOR

Unless one wishes to feed pigs a limited ration, self-feeding is more efficient than hand-feeding.

1436. Soaking grain; feeding slop; cooking feed.—If shelled or ear corn becomes very hard and dry on storage, it may pay to soak it before feeding to swine, though the increase in value is not usually very marked. When whole barley or oats cannot conveniently be ground, it may be economical to soak the grain, though soaking it is a rather poor substitute for grinding. It does not generally pay to soak ground grain or a mixture of concentrates for swine.[140]

Years ago it was a common practice to feed grain mixtures to swine in the form of slop or swill. Experiments have shown, however, that slop-feeding is not generally superior to dry-feeding.[141]

1437. Pelleted feed.—A general discussion of pelleting feed has been given in Chapter IV. (91) As there stated, the cost of pelleted feeds compared with ordinary rations will largely determine whether pelleted feeds will be economical. For feeding growing and fattening pigs the entire ration, including ground grain, may be pelleted, or a pelleted protein supplemental mixture may be self-fed, usually free-choice, with corn or other grain.

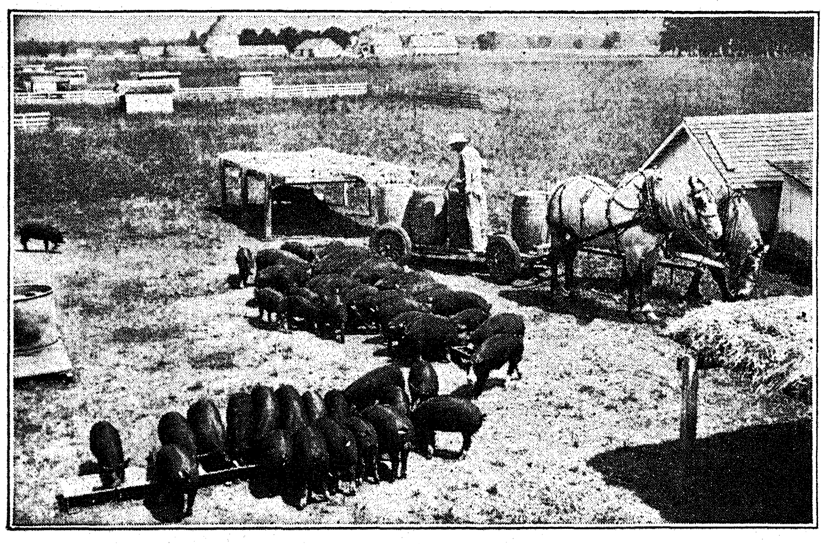
Several experiments have been conducted recently to compare pelleted feed with usual rations for pigs.[143] In these trials a self-fed pelleted ration of such a

mixture as ground barley and supplements has generally produced appreciably more rapid gains than self-feeding the same mixture in meal form. Also, less feed has usually been required per 100 lbs. gain on the pelleted ration.

The saving in feed needed per 100 lbs. gain by pelleting such a ration has differed widely, ranging from 8 per cent to more than 40 per cent in a case where there was much wastage of the meal ration around the self feeders. Usually the

When ear corn is fed in summer on pasture lots that are free from infestation with parasites, there may be no appreciable advantage in using feeding platforms.[145]

1439. Temperature; shade; wallows.—Because swine have little ability to get rid of excess heat, they suffer greatly in very hot weather unless they have access to a wallow where they can wet their bodies, and unless good shade is provided. (233–234)



SLOP-FEEDING HAS BEEN MOSTLY DISCONTINUED

Slop-feeding is not generally superior to dry-feeding, and it requires more labor.

saving by pelleting a ration of this kind will not be more than about 20 per cent. There is apparently much less advantage in pelleting a mixture of ground corn and supplements.

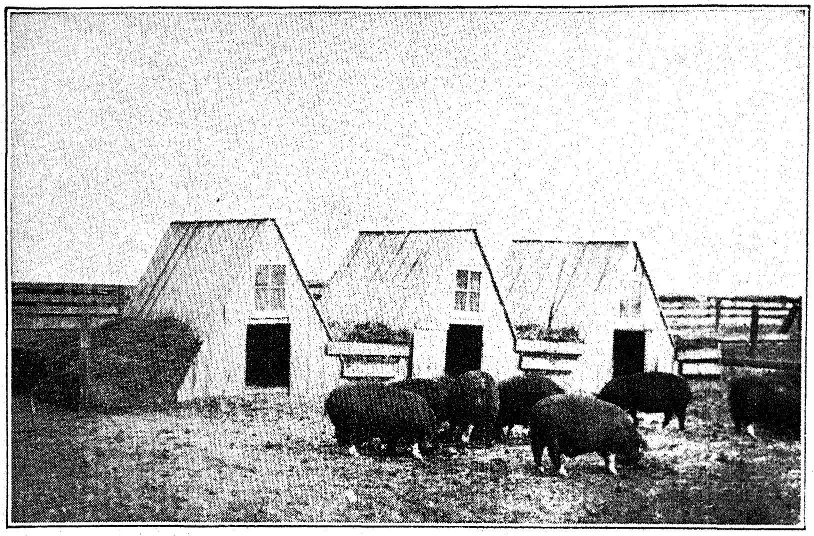
1438. Feeding platforms.—It is advisable to place self-feeders on platforms in the pasture or outside lot, so that the pigs can salvage feed that may be nosed out of the self-feeder. It also pays well to have feeding platforms in hog lots where ear corn is fed during the rainy season. Thus, in a Kentucky test during the fall, the feed cost of 100 lbs. gain was 14 per cent less when ear corn was fed on a platform than when it was fed on the muddy ground.[144]

In California experiments in which swine were kept in rooms where the temperature and the humidity were both controlled, a continued air temperature of 100° F. even caused death, if the skin was not wet.[146] The cooling effect of evaporation from the wet body surface was very important at high air temperatures.

The importance of shade in hot weather is shown by Mississippi trials.[147] Exposure to sunlight for only 15 minutes at air temperatures of 82 to 90° F. caused distress in pigs, raising the body temperature and greatly increasing the respiration rate. Providing good shade for growing and fattening pigs increased the

gain and the feed efficiency. These experiments show that where the summer weather is very hot, it is extremely important to provide a sanitary concrete or portable wallow for swine, and also plenty of shade.[148]

In the California studies, pigs weighing 50 to 125 lbs. made the most rapid and efficient gains at an air temperature of about 73° F., while a temperature of about 61° F. was optimum for heavier hogs.



COLONY HOUSES BANKED WITH STRAW FOR WINTER

Colony houses thus protected provide comfortable winter quarters for all but small pigs, even in the northern states.

Where the summers are very hot, pigs make more rapid and more economical gains in winter than in summer.[149]

1440. Shelter.—Even where the winters are cold, inexpensive shelter is all that is necessary for swine. The essentials for healthful winter shelter are freedom from dampness, good ventilation without drafts, sunlight, reasonable warmth, and a moderate amount of dry bedding. The quarters should be on well-drained ground and be so arranged that they can be thoroughly cleaned and disinfected.

Swine may be housed in a central hog house with a number of pens or in small portable houses, or colony houses. Many use a combination of the two systems, for in the northern states the central house is well suited for winter shelter and early spring farrowing, while the portable houses are particularly useful for housing pigs on pasture.

Portable houses may also be used for winter shelter, even where the weather is cold. They will be fairly warm if corn stalks, horse manure, or other litter is banked against the sides of the houses. A strong sack may be hung in the doorway to keep out the cold and yet allow the hogs to go back and forth at will. For very young pigs a lantern may be hung in the portable house to keep the temperature comfortable.

Even in the northern states, brood sows wintered in cheap portable houses do not require much more feed than do those in a central house, especially if the houses are well protected. In trials during 4 winters at the Wisconsin Station, pregnant gilts were wintered in shed-roof colony houses made of a single thickness of boards.[150] The opening through which the sows entered was left open

at all times so they could come and go at will, and no litter was banked up against the houses to make them warmer. At farrowing time the sows were removed to farrowing pens in the central barn.

The feed cost of wintering these sows was 16 per cent higher than for sows kept in a central hog barn and allowed to run at will in an exercise paddock during the day. However, this greater feed cost was offset by the fact that a larger proportion of the pigs from the sows housed in the portable houses were vigorous. This was probably because the sows took more exercise; they were out in the sunlight more; and they were able to get a small amount of green grass from the paddocks in which the portable houses were located. All these factors are important in enabling sows to produce thrifty litters.

For very young pigs, there is more advantage from warmer shelter. In the northern states a well-ventilated central hog house is therefore best for sows that farrow in cold weather. However, even in the northern part of the corn belt, many farmers raise early spring pigs very successfully in well-protected colony houses.

Fall pigs that get a good start before cold weather comes on will do well in portable houses during northern winters. For example, in 3 Michigan trials fall pigs housed in portable houses during winter made as rapid gains as those in a central house, and they required no more feed per 100 lbs. gain.[151]

Where the winters are more severe, a considerable saving in feed may be made by providing warmer shelter. Thus, at the Ottawa, Ontario, Station pigs weighing 70 lbs. at the start that were housed in portable houses during the winter required 44 per cent more feed than others in a well-built central house.[152] Brood sows in the portable houses required only 25 per cent more feed than those in the warmer quarters, showing that large animals can withstand severe cold better than small ones. The health of the animals was good under both conditions.

EXERCISE IS IMPORTANT FOR BROOD SOWS IN WINTER

Brood sows housed in these unprotected colony houses at the Wisconsin Station required 16 per cent more feed than those kept in a central hog house, but the percentage of vigorous pigs they farrowed was higher, because they took more exercise.

In a Kansas test during a winter in which the temperatures at 8 a. m. ranged from 31° F. to −12° F., large hogs in warm quarters required 25 per cent less feed than those kept without shelter in a yard protected only by a high board fence on the north.[153]

1441. Exercise.—Sufficient exercise is highly important for breeding swine and also for young pigs.[154] Even for fattening pigs, limited exercise is preferable to very close confinement. In addition to the benefits from the exercise itself, when

swine are out-of-doors in outside paddocks a considerable part of the day they are protected against a deficiency of vitamin D, through the effect of direct sunlight. Also, swine that have access to outside paddocks may get some green feed, even during the winter. Though the amount of green forage they eat may be small, it is often of much value in keeping them thrifty.

So that brood sows will exercise in winter, it is advisable to feed them at the end of the paddock farthest from their sleeping quarters. Here there should be a rack filled with choice legume hay. The sows will thus not only secure needed vitamins, calcium, and protein, but also they will get considerable exercise, instead of lying in their pens most of the time.

Indiana experiments show that too much exercise reduces the gains and the feed efficiency of growing and fattening pigs.[155] Pigs that were exercised by driving them one-half mile each day made less rapid gains and required slightly more feed per 100 lbs. gain than others which were confined to a small feed lot.

1442. Barrows; sows.—Up to the usual market weights, barrows make only a trifle more rapid and economical gains than do open sows. The slight difference is due to restlessness of the sows during the estrus periods. In Wisconsin and Minnesota studies the difference in average daily gains for barrows and gilts was only 0.02 to 0.08 lb. per head daily.[156]

In experiments where the yields of dressed carcass and of the various cuts from barrows and from unbred gilts have been determined, there has been no consistent difference in the dressing percentage.[157] Gilts tend to have a slightly smaller proportion of fat at a given age, which is opposite to the condition in cattle. The yield of hams is generally slightly higher for gilts, and that of bacon slightly less. In an Illinois test the meat from barrows was slightly tougher, on the average, than from gilts.[158]

In the chief pork producing regions of this country it is a common practice to fatten sows for market following the weaning of their first or second litters. In a Wisconsin trial thin sows fed a well-balanced ration gained 2.5 lbs. a day for a period of 56 days and required about the same amount of feed per pound of gain as growing and fattening pigs fed a similar ration.[159]

Many farmers follow the practice of breeding the sows at the beginning of the fattening period, as they believe this results in faster and more economical gains. In South Dakota tests in which sows were fattened for about 2 months, the average daily gain of sows that had been bred was 0.26 lb. more than for sows that had not been bred, and the feed cost per 100 lbs. gain was 77 cents less.[160] However, these advantages were more than offset by the fact that the bred sows sold for an average of 34 cents less per hundredweight.

Slaughter tests showed that the bred sows averaged slightly lower in dressing percentage, in grade of carcass, and especially in grade of bacon belly. It was concluded that the breeding of sows during the fattening period was undesirable from the standpoint of both producer and packer.

Spaying sows before fattening them is of no advantage, for unspayed sows make just as good gains.[161]

1443. Types of swine.—It is outside the scope of this book to discuss the breeds and breeding of livestock. Therefore, only certain very general statements can be made concerning the types of swine.

Extensive swine breeding investigations have been and are being conducted by the United States Department of Agriculture, in cooperation with several of the state experiment stations. The object of these experiments is to develop strains or breeds of swine that excel in rate and economy of gain and that produce the kind of carcasses that meet present-day demands better than the former lard-type hogs.

In addition to producing strains or lines of the older breeds which meet these demands better, new breeds have been developed by crossing swine of our common American breeds with the bacon breeds. Such new breeds are Beltsville

No. 1 and No. 2, Maryland No. 1, Minnesota No. 1 and No. 2, and Montana No. 1.

Experiments show that the amount of feed required per 100 lbs. gain to market weights by meat-type hogs is no greater and usually somewhat less than for the old-fashioned over-fat kind.[162]

The modern meat-type hogs meet the demand in this country for leaner but well-finished carcasses. For the production of very superior bacon, which commands a decided premium in Great Britain and some other countries, the distinct bacon breeds are preferred.

1444. Swine improvement; production records.—In order to secure the best returns from swine it is necessary to have well-bred breeding stock. The sows and boar should be carefully selected from strains of swine that excel in the following characteristics: (1) They produce good-sized litters of thrifty pigs; (2) their pigs make rapid gains and therefore usually economical gains; (3) their pigs yield carcasses that meet the present market demands.

Disposition and milk yield are also important factors to consider in selecting sows to retain in the herd. If a sow has a mean disposition or if she is careless, she may crush or injure a considerable percentage of the pigs she farrows. If a sow does not have a good flow of milk, her pigs will fail to make good gains.

A herd record should be kept in which the number of pigs farrowed and the number raised by each sow are recorded, with notations as to whether the pigs make good gains. Only gilts from the best sows, as shown by this record, should be retained for the breeding herd. To identify the pigs, they should be ear-notched or otherwise marked at birth.

Outstanding progress has been made in Denmark and certain other European countries in using production records for swine improvement. In Denmark herds of swine of approved type are designated as breeding centers.[163] To ascertain the strains which are superior in these herds, 4 pigs are selected from a litter and fed to market weights on a standard ration at a central feeding station, where a careful record is kept of feed consumed and gains made. Representative pigs from each litter are slaughtered in order to secure data on the desirability of the carcasses. This method of swine testing has also been used effectively in Canada.

Since rapid-gaining pigs usually make the most economical gains, pig-recording systems have been developed in Sweden, Great Britain, and some other countries. These are often combined with the milk-recording service for dairy herds. Under these systems the pigs are ear-notched and weighed at a definite age by an inspector. These records are used as a basis for the selection of breeding stock.

In order to promote more efficient pork production, various swine registry associations in this country have adopted a standardized "production registry" for brood sows and boars. To qualify for entry in the production registry, a sow must meet certain definite requirements, based on the number of pigs raised per litter in 2 litters and on the total weight of the litter at 56 days of age. Boars are admitted to the production registry when they have sired a certain number of sows that have qualified for the registry.

1445. Dressing percentage.—It was found in studies by the United States Department of Agriculture that the dressing percentage in winter of hogs dressed "shipper style," with heads on and without the leaf fat, kidneys, and ham facings being removed, averaged 78 per cent, based on purchase weights and for hogs in transit 12 hours after purchase.[164] The dressing percentage averaged only 74.5 per cent for hogs in transit 84 hours. It was slightly lower in summer than in winter. The dressing percentage for hogs dressed "packer style," with the head off and the leaf fat, kidneys, and ham facings removed, will be about 8 per cent less than for those dressed "shipper style."

The chief factor affecting the dressing percentage is the degree of fatness. It has been pointed out previously that when pigs are fed a limited ration during the finishing period, the dressing percentage is a little lower than in the

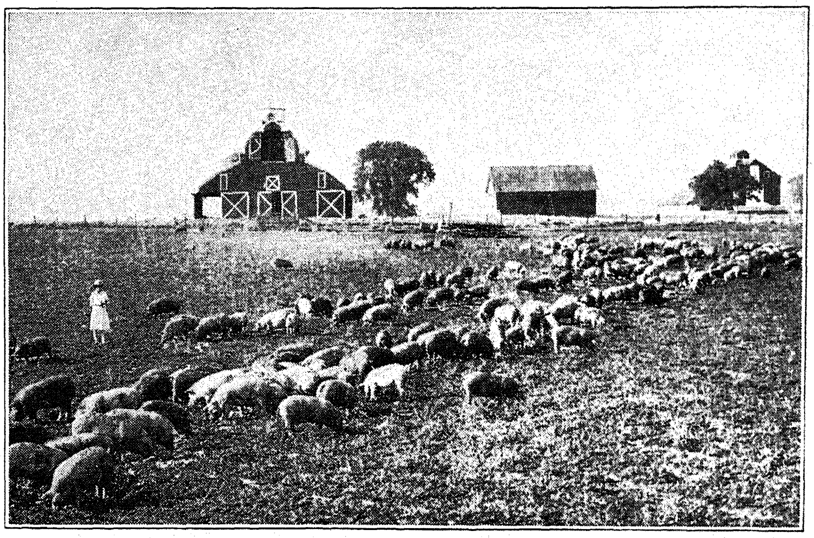
case of full-fed pigs at the same market weight. (1429)

In Ohio studies there was a low point in dressing percentage in September and October, probably due to the marketing of pigs that were not very well finished.[165] The dressing percentage then increased gradually and reached a high point in January and February.

1446. Soft pork.—Certain feeds, especially soybeans, peanuts, rice bran, rice polish, and chufas, tend to produce soft pork when fed to pigs in considerable amounts. The products from hog carcasses that are soft are undesirable from the standpoint of both the processor and the consumer, and therefore sell at a decided discount.

Lard from soft hogs does not harden at ordinary temperatures. The bacon is soft and flabby, and it is difficult to slice, even with a machine. The loins are smeary and unattractive. The hams are less affected, as they have a smaller proportion of fat. When the pork is very soft, oil will drip from hams or bacon in the smoke house, thus increasing the shrinkage. Unless the carcass is extremely soft, the meat after cooking may be just as attractive and palatable as that from a firm carcass. However, there will be more wastage in cooking, because of a greater loss of fat.

It is impossible to determine whether or not hogs will have soft carcasses by handling them when alive, as the fat is fluid at body temperature even in the case of hogs that yield hard carcasses. In sections where there is considerable trouble from soft pork, the packer usually protects himself against loss by paying a lower price for all hogs, or buys them subject to a discount if they kill soft.



FATTENING PIGS FED EAR CORN ON PASTURE

Corn is most commonly fed to swine in the form of ear corn or shelled corn.

Extensive experiments have been conducted by the United States Department of Agriculture and various experiment stations to study the soft pork problem and especially to find the extent to which softening feeds can be used without producing soft pork.[166]

These investigations have shown that the body fat which swine make from carbohydrates or protein in their food has a melting point sufficiently high to be hard and firm at ordinary room temperatures. However, fat in the feed may be converted into body fat with but little change. Therefore, when swine receive

such feeds as soybeans and peanuts, that are high in fat, much of the fat deposited in their bodies comes from this source. Since the fat in these feeds is liquid at ordinary temperatures, soft pork results if much of the body fat comes from this source.

The grains also contain fat which is liquid at ordinary temperatures and which will produce soft pork if fed in large enough amounts. However, the percentage of fat in the grains is relatively low. When pigs are fed on grain and supplements that are not high in fat, most of the body fat is therefore made from the carbohydrates, and not from the fat in the feed. Such rations hence produce firm pork.

Corn and oats, which have considerably more fat than the other grains, have some tendency to soften pork. Oats have a more marked effect than does corn, because of their higher fat content. Barley, wheat, rye, and the grain sorghums tend to produce hard pork, because of their lower fat content.

When pigs are well fattened on corn and such supplements as tankage, meat scrap, fish meal, or dairy by-products, their carcasses are sufficiently firm and hard to meet the requirements of the markets in the United States. However, for the production of the type of bacon that commands a premium in England, a harder carcass is necessary. Therefore, corn should not form too large a part of the ration when such bacon is to be produced.

Pigs that make rapid gains usually yield firmer carcasses than do pigs which have gained only slowly on the same combination of feeds. This is because fast-gaining pigs make a larger proportion of the stored fat from carbohydrates in the ration, and less comes from the fat in the feed.

1447. Preventing soft pork.—In using feeds that have a softening effect on the carcass, soft pork can be prevented when either of two methods is used: (1) The softening feed is fed only to brood sows and to young pigs up to certain weights. The pigs are then fed until they reach market weight on a ration which produces hard pork. (2) A hardening ration is fed to the pigs until they reach certain weights, and then they are fed a ration which includes only a very limited proportion of the softening feed. (**804**)

North Carolina investigations show that to produce firm carcasses pigs cannot be fed a total per head of more than 90 to 100 lbs. of peanuts (on the shelled basis).[167] The peanut feeding must start when the pigs weigh 60 lbs. or less, and after the stated amount has been fed, the pigs should be finished on a hardening ration of corn and supplements, containing 13 to 15 per cent of cottonseed meal. The gain in weight during the hardening period should be 3.5 times that during the period when peanuts are fed.

As stated in Chapter XXII, nearly one-third of the peanut acreage in this country is harvested by hogging down with growing and fattening pigs, in spite of the fact that this produces soft pork. (**839**) This is because of the cheapness of this method of producing pork.

It is also shown in Chapter XXII that more than 10 per cent of soybeans in the ration has a decided softening effect on the carcass, if continued throughout the fattening period. (**804**) The tendency to produce soft pork is reduced if pigs in dry lot weigh at least 125 lbs. when soybean feeding is begun, and those on pasture at least 75 lbs. Hogging down ripe soybeans produces soft pork. Soybean oil meal does not produce soft pork when fed in any ordinary amount.

The effects of other feeds upon the character of pork have been discussed in the various chapters of Part II. If a ration for pigs contains more than one-half hominy feed of the usual fat content, the carcasses are apt to be somewhat soft. (**708**) Too large a proportion of rice bran or rice polishings produces a marked softening effect on the carcass. (**784, 785**)

Certain feeds have much more of a hardening effect than a ration of corn and tankage. Cottonseed meal has such an effect. Therefore an excellent ration for hardening the carcasses is corn sup-

plemented by a combination of cottonseed meal and either tankage or fish meal. (818) Brewers' rice and sweet potatoes also produce firm pork, because of the very low content of fat.

1448. Production of high-quality bacon.—Consumers generally prefer bacon that has a good "streak" of lean meat, and which is firm and of fair thickness. In the United States most of the best bacon is made from the leaner pigs of the meat type. However, in Great Britain there has long been a demand for a very superior quality of bacon, marketed under the name of "Wiltshire sides."

This demand is met by pigs produced there and by importation, chiefly from Denmark, Ireland, and Canada. A Wiltshire side comprises the entire half of the dressed pig, minus the head, shanks, shoulder bone, and hip bone. All of the side, except the ham and the shoulder, is sold as "bacon."

Wiltshire sides are made from choice pigs that have proper length of body, a high proportion of lean meat, a medium covering of fat on the back (preferably 1.0 to 1.5 inches thick) and bellies smoothly finished with firm fat. Even a slight degree of softness of fat, that would not be very objectionable on our markets, will disqualify a carcass for high-quality Wiltshire sides.

Full-feeding pigs a concentrated ration throughout growth and fattening is apt to produce carcasses having too much fat and too little lean to meet the requirements for Grade A bacon carcasses on Canadian markets. It has been shown previously that the carcasses are leaner when pigs are fed liberally during early growth and then are restricted in energy intake during the finishing period. (1429)

Hand-feeding a limited ration after the pigs reach a weight of 100 to 125 lbs. is one way of reducing the energy intake. However, this requires more labor than does self-feeding. Also, the greediest pigs often get much more than their share of feed, and as a result are actually full-fed.

Recent Canadian experiments show that the desired type of carcass can be secured if sufficient very bulky feed, such as ground legume hay or wheat bran, is included in a self-fed mixture, so as to reduce the gain during the finishing period to about 1.25 lbs. per head daily.[168] Pigs thus fed may require slightly more feed per 100 lbs. gain than those which are full-fed a concentrated ration. However, this will be offset by the larger proportion of the carcasses that receive the Grade A premium on the Canadian markets.

Barley ranks above wheat or corn for the production of bacon of highest quality. It not only produces firm carcasses, but also it tends to produce a larger proportion of lean, because it has somewhat more fiber. However, when barley is the only grain in a full-fed ration, leaner carcasses are produced when the nutrient intake is reduced during the finishing period. Therefore, feeding a combination of barley and oats or adding a still more bulky feed makes leaner carcasses.

Skimmilk, buttermilk, or whey, fed in combination with grain, make excellent bacon. Such pastures as alfalfa, clover, or rape also help to produce high-quality bacon carcasses.

QUESTIONS

1. Compare the efficiency of pigs and other classes of stock as meat producers.
2. Discuss the rate and economy of gain by pigs of various weights.
3. At what weights should pigs commonly be marketed in the United States?
4. Why do swine suffer from nutritive deficiencies more frequently than do cattle, sheep, or horses?
5. Compare the ability of swine and of ruminants to digest various classes of feeds.
6. Discuss the importance of good pasture or legume hay for swine.
7. Name 5 protein supplements that provide protein of good quality for swine.
8. Name 7 protein supplements that are unsatisfactory when fed as the only supplements to swine not on pasture.
9. Discuss the amounts of protein required by swine.
10. State a common ration that is deficient in tryptophan for young pigs. How can the lack be corrected?

11. State a combination of feeds that is well adapted to self-feeding by the free-choice plan. State a combination of feeds which is not suited to free-choice feeding.
12. Discuss the use of protein supplements with the cereal grains for pigs not on pasture.
13. Under what conditions would you feed a protein supplement to pigs fed grain on good pasture? When is it more economical not to use a supplement?
14. Discuss the need of pigs for fat.
15. What is the effect of adding surplus animal fat to a ration for pigs?
16. Of what importance is the fiber content in rations for growing and fattening pigs?
17. Discuss the requirements of swine for salt.
18. State in detail the kind of rations for swine: (a) That require a calcium supplement; (b) that require a phosphorus supplement; (c) that need no calcium or phosphorus supplement.
19. What are the approximate minimum percentages of calcium and of phosphorus that swine rations should contain?
20. How can goiter or hairlessness in new-born pigs be prevented?
21. Give 3 methods of preventing anemia in suckling pigs.
22. Discuss the trace mineral needs of swine.
23. Discuss the use of simple versus complex mineral mixtures for swine.
24. State the conditions under which swine have an abundant supply of vitamin A value and the conditions under which there will be a deficiency.
25. State the same facts for vitamin D.
26. Which B-complex vitamins may be deficient in balanced rations for swine?
27. What feeds will correct a lack of: (a) Riboflavin; (b) niacin; (c) pantothenic acid; (d) vitamin B_{12}?
28. What is known about the need for unidentified vitamins by young pigs?
29. Under what conditions is it beneficial to add a B-complex supplement to rations?
30. Discuss the importance of legume hay as insurance against vitamin deficiency.
31. In what sort of ration for growing and fattening pigs would you use only 5 per cent of legume hay? In what kind of ration would you use 10 to 15 per cent of legume hay?
32. Discuss the use of other vitamin supplements for dry-lot feeding.
33. What is a trio mixture? Why are trio mixtures and similar combinations superior to tankage or fish meal as the supplement to grain for young pigs in dry lot?
34. In what different ways may a trio mixture and similar combinations be fed?
35. In what ways can the trio mixture be modified?
36. State the formula for another efficient supplemental mixture for pigs not on pasture.
37. State 2 combinations that are superior to tankage or meat scrap alone as the supplement for pigs on pasture.
38. Discuss antibiotic feed supplements for: (a) Growing and fattening pigs; (b) brood sows.
39. Would you add an arsonic supplement or a surfactant to an efficient ration that contains an antibiotic supplement?
40. Discuss hormones for pigs.
41. Discuss the water requirements of swine.
42. At what times during the year should pigs be marketed to bring the highest prices, on the average?
43. What effect may the level of feeding have on the carcasses of pigs?
44. Discuss limited-feeding vs. full-feeding of pigs: (a) On pasture; (b) in dry lot.
45. What results have been secured in experiments in which self-feeding of pigs has been compared with hand-feeding: (a) In dry lot; (b) on pasture?
46. What grains should commonly be ground for swine?
47. What feeds for swine may be improved by soaking?
48. Under what conditions may it be desirable to feed concentrates to pigs in the form of a slop?
49. Discuss: (a) Cooking feed; (b) pelleting feed; (c) use of feeding platforms.
50. How can the bad effect of very hot weather on swine be prevented?
51. Discuss: (a) Shelter for swine; (b) exercise; (c) barrows vs. gilts; (d) fattening sows.
52. What type of swine best meets present consumer demands in this country?
53. What methods have been used in Europe for improving the quality of swine carcasses and increasing the efficiency of production?
54. What is the production registry for swine?
55. What is the average dressing percentage of swine in winter?

56. Discuss the soft pork problem, stating the feeds that produce soft pork and describing the extent to which peanuts can be fed to pigs without producing soft pork.
57. Discuss the special requirements for the production of choice bacon to be marketed as "Wiltshire sides."

REFERENCES

1. Hogan, Weaver, Edinger, and Trowbridge, Mo. Res. Bul. 73.
2. Beeson, Crampton, Cunha, Ellis, and Luecke, National Research Council, Nutrient Requirements for Domestic Animals, II, Swine, Revised 1953; see also: Vestal, Ind., mimeo. rpts.; Hogan, Weaver, Edinger, and Trowbridge, Mo. Res. Bul. 73; Loeffel, Derrick, and Peters, Nebr. Bul. 351; Robison, Ohio Bul. 335; Hankins and Ellis, U.S.D.A. Cir. 731; Menzies-Kitchin, Jour. Min. Agr., Great Britain, 49, 1942, p. 174.
3. Atkinson and Klein, U.S.D.A. Tech. Buls. 894, 917.
4. Hanson, Minn. Farm and Home Sci., 11, 1954, No. 2.
5. Fraps, Tex. Bul. 454; Crampton and Whiting, Canada, Sci. Agr., 23, 1943, pp. 518–526, 725–731; Crampton and Bell, Canada, Sci. Agr., 25, 1944, pp. 43–50.
6. Mitchell and Kelley, Ill. and U.S.D.A., Jour. Agr. Res., 56, 1938, pp. 811–829; Heady, Catron, Ashton, and Woodworth, Iowa Farm Sci., 8, 1954, No. 9; Crampton and Bell, Canada, Sci. Agr., 22, 1942, pp. 390–400.
7. Krider et al., Ill., Jour. Anim. Sci., 3, 1944, pp. 107–119; 4, 1945, pp. 410–419; 5, 1946, pp. 406–407, 419–420; Gard, Terrill, and Becker, Ill., Jour. Anim. Sci., 14, 1955, pp. 562–572; Catron, Thomas, and Shearer, Iowa Rpt. 1948; Hogan and Johnson, Mo. Res. Buls. 321, 322; McRoberts and Hogan, Mo., Jour. Nutr., 28, 1944, pp. 165–174; Teague, Ohio, Jour. Anim. Sci., 14, 1955, pp. 621–627; Cunha, Warwick, Ensminger, and Hart, Wash., Jour. Anim. Sci., 7, 1948, pp. 117–126; Ross, Phillips, Bohstedt, and Cunha, Wis., Jour. Anim. Sci., 3, 1944, pp. 406–414; Cunha, Ross, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 3, 1944, pp. 415–421; Stevenson, Ellis, and Davis, U.S.D.A., Jour. Anim. Sci., 13, 1954, pp. 1000–1001.
8. Johnson, Ark., Jour. Anim. Sci., 3, 1944, pp. 136–142; see also: Culbertson, Iowa Farm Service Reporter, 6, 1945, No. 1.
9. Noland and Baugus, Ark. Farm Res., 2, 1953, No. 4; Cunha et al., Fla., Arch. Biochem. and Biophys., 24, 1950, p. 455; Wallace et al., Fla. Rpt. 1953; Becker, Lassiter, Terrill, and Norton, Ill., Jour. Anim. Sci., 13, 1954, pp. 611–621; Terrill et al., Ill., Jour. Anim. Sci., 13, 1954, pp. 622–629; Lassiter, Terrill, Becker, and Norton, Ill., Jour. Anim. Sci., 14, 1955, pp. 482–491; Catron et al., Iowa, Jour. Anim. Sci., 11, 1952, pp. 221–232; Jensen et al., Iowa, Jour. Anim. Sci., 14, 1955, pp. 69–81; Hoefer, Luecke, Thorp, and Johnston, Mich., Jour. Anim. Sci., 11, 1952, pp. 455–458; Aunan, Hanson, and Ferrin, Minn. Mimeo. Rpt. H-129; Tribble and Pfander, Mo., Jour. Anim. Sci., 14, 1955, p. 1224; Meade, Nebr., Jour. Anim. Sci., 15, 1956, pp. 297–306; Robison, Ohio, Mimeo. Series 86; Whitehair and Hillier, Okla. Misc. Pub. MP-27; Hillier, MacVicar, and Pond, Okla. Misc. Pub. MP-31; Burnside, Grummer, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 13, 1954, pp. 184–200; Kropf et al., Wis., Jour. Anim. Sci., 14, 1955, pp. 1230–1231; Stevenson, Hiner, and Ellis, U.S.D.A., Jour. Anim. Sci., 14, 1955, p. 1233; McElroy, Lobay, and Sinclair, Canada, Jour. Anim. Sci., 7, 1948, pp. 494–500.
10. Terrill, Ill., A. S. Mimeo. Rpt. 266.
11. Heady, Woodworth, Catron, and Ashton, Iowa Res. Bul. 409.
12. Catron, The Pork Costulator.
13. Becker, Jensen, Terrill, and Norton, Ill., Jour. Anim. Sci., 14, 1955, pp. 1086–1094; Becker et al., Ill., Jour. Anim. Sci., 14, 1955, pp. 664–673; Mertz, Shelton, and Beeson, Ind., Jour. Anim. Sci., 8, 1949, pp. 524–531; Shelton, Beeson, and Mertz, Ind., Jour. Anim. Sci., 10, 1951, pp. 57–64, 73–79; Beeson, Jackson, and Mertz, Ind., Jour. Anim. Sci., 12, 1953, pp. 870–875; Jackson, Mertz, and Beeson, Ind., Jour. Nutr., 51, 1953, pp. 109–116; Mertz, DeLong, Thrasher, and Beeson, Ind., Jour. Anim. Sci., 14, 1955, pp. 1217–1218; Brinegar et al., N.Y., Jour. Nutr., 42, 1950, pp. 129–138, 619–624; Curtin et al., N.Y., Jour. Anim. Sci., 11, 1952, pp. 459–464, 759–760; Eggert, Maynard, Sheffy, and Williams, N.Y., Jour. Anim. Sci., 14, 1955, pp. 556–561.
14. Sewell et al., N.Y., Jour. Anim. Sci., 11, 1952, pp. 775–776; Sewell et al., N.Y., Jour. Nutr., 49, 1953, pp. 435–441; Eggert et al., N.Y., Jour. Nutr., 53, 1954, pp. 177–184; see also: Becker, Ullrey, and Terrill, Ill., Jour. Anim. Sci., 13, 1954, pp. 346–356.
15. Miner, Clower, Noland, and Stephenson, Ark., Jour. Anim. Sci., 14, 1955, pp. 24–29; Terrill, Becker, Warden, and Adams, Ill., Mimeo. Rpt. A. S. 266b; Catron et al., Iowa, Jour. Anim. Sci., 12, 1953, p. 910; Bloss et al., Mich., Jour. Anim. Sci., 12, 1953, pp. 102–106; Hanson, Ferrin, and Anderson, Minn., Mimeo. Rpt. H-100; Pfander and Tribble, Mo., Jour. Anim. Sci., 14, 1955, pp. 545–555; Eggert, Brinegar, and Anderson, Nebr., Jour. Anim. Sci., 10, 1951, p. 1047; Curtin, Loosli, Willman, and Williams, N.Y., Jour. Anim. Sci., 11, 1952, pp. 459–464; Hillier, MacVicar, and Pond, Okla. Misc. Pub. MP-31; Hillier, MacVicar, and Ewing, Okla. Misc. Pub. MP-43; Schneider, Goodwin, and Ensminger, Wash., Jour. Anim. Sci., 10, 1951, p. 1061; Blight and Powick, U.S.D.A., Jour. Anim. Sci., 10, 1951, p. 1039.
16. Aubel and Connell, Kan. Rpt. 1932–34.
17. Joseph, Mont. Bul. 169; Vinke and Bergstedt, Mont. Bul. 284; Burkitt, Flower, DePape, and Watt, Mont. Mimeo. Cir. 60; S.D. Rpt. 1931; Smith and Maynard, Utah Bul. 254.
18. Thomas and Kincaid, Va. Rpt. 1950.
19. Fla. Rpt. 1945; Becker, Krider, VanPoucke, and Carroll, Ill., mimeo. rpt.; Weaver, Mo Bul. 285; Loeffel, Nebr. Rpts. 1928, 1929, 1930, 1934, 1936; Miller, Penn. Bul. 446.
20. Vestal, Ind., mimeo. rpts.; Evvard, Culbertson, et al., Iowa, mimeo. rpt.; Culbertson, Thomas, Hammond, and Beard, Iowa,

mimeo. rpts.; Ferrin, Minn., mimeo. rpt.; Robison, Ohio Bul. 552; Godbey, S.C. Bul. 274; Wilson and Wright, S.D. Bul. 262.

21. Vestal, Ind. Bul. 300 and mimeo. rpt.; Evvard and Culbertson, Iowa, mimeo, rpt.; Aubel and Connell, Kan., mimeo. rpt.; Loeffel, Nebr., mimeo. rpt.; Robison, Ohio Bul. 552.
22. Thompson and Voorhies, Cal. Bul. 342; Osland and Morton, Colo. Bul. 381; Freeman, Mich. Quar. Bul., 15, 1933, No. 4; Joseph, Mont. Bul. 236; Headley, Nev. Bul. 175; Wilson and Wright, S.D. Bul. 262; Smith and Maynard, Utah Bul. 254.
23. Robison, Ohio Bul. 552; Smith et al., Tenn., information to the author.
24. Vestal, Ind., mimeo. rpts.; Robison, Ohio, mimeo. rpts.; see also: Aubel, Kan. Cir. 287; Robison, Ohio Bul. 673; Oliver, Ore. Cir. of Inf. 490; Gobble, Miller, Ziegler, and Bentley, Penn. Bul. 516.
25. Shrewsbury and Vestal, Ind. Rpts. 1942, 1943; Ellis and Zeller, U.S.D.A., Jour. Biol. Chem., 89, 1930, pp. 185–197; see also: Robison, Ohio Bul. 664 and Ohio Bimo. Bul. 224.
26. Witz and Beeson, Ind., Jour. Anim. Sci., 10, 1951, pp. 112–128.
27. Kropf, Pearson, and Wallace, Fla., Jour. Anim. Sci., 13, 1954, pp. 630–637; Alsmeyer, Palmer, Wallace, and Shirley, Fla., Jour. Anim. Sci., 14, 1955, p. 1226; Baird, Ga., Jour. Anim. Sci., 14, 1955, pp. 1192–1193; Perry and Beeson, Feed Age, December, 1953; Peo, Ashton, Speer, and Catron, Iowa, Jour. Anim. Sci., 13, 1954, p. 995; Aubel and Richardson, Kan. Cir. 308; Sheffy, Holmes, DeCosta, and Willman, N.Y., Jour. Anim. Sci., 14, 1955, pp. 1222–1233; Barrick et al., N.C., Jour. Anim. Sci., 12, 1953, p. 899; Hillier, Okla. Misc. Pub. MP-17; Day, Anderson, Johnson, and Lewis, West Va., Jour. Anim. Sci., 12, 1953, pp. 944–945.
28. Vestal, Beeson, and Wiley, Ind. Rpt. 64; Evvard, Iowa Res. Bul. 118; Weaver, Mo. Bul. 520; Teague and Hanson, Nebr., Jour. Anim. Sci., 13, 1954, pp. 206–214; Robison, Ohio Bimo. Bul. 145; Hillier, Whatley, Whiteman, and Gard, Okla. Misc. Pub. MP-22; Oliver and Potter, Ore. Bul. 269; Merkel et al., Wis., Jour. Anim. Sci., 12, 1953, p. 903; 14, 1955, p. 1232; Axelsson and Ericksson, Sweden, Jour. Anim. Sci., 13, 1954, pp. 881–891.
29. McCormick and Kidwell, Nev. Cir. 2; Bohman, Kidwell, and McCormick, Nev., Jour. Anim. Sci., 12, 1953, pp. 876–880; Bohman, Hunter, and McCormick, Nev., Jour. Anim. Sci., 13, 1954, p. 977.
30. Aubel, Kan. Cir. 287; Loeffel, Nebr. Rpt. 1924; Hale, Tex. Rpts. 1925, 1926; Sinclair, Sci. Agr., Canada, 20, 1939, pp. 109–119.
31. Vestal, Ind., mimeo. rpts.; Grummer and Bohstedt, Wis. Bul. 472; see also: Kirk and Crown, Fla. Bul. 372; Evvard and Culbertson, Iowa Leaflet 9 and mimeo. rpts.; Nebr. Rpt. 1924; Galgan and Johnson, Wash. Cir. 80; Sinclair and Sackville, Sci. Agr., Canada, 6, 1926, pp. 373–379.
32. Meyer, Grummer, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 9, 1950, pp. 300–306.
33. Grummer and Bohstedt, Wis. Bul. 498.
34. Aubel, Hughes, and Peterson, Kan., Jour. Agr. Res., 62, 1941, pp. 531–542; Aubel, Hughes, and Roderick, Kan. Rpts. 1942–44, 1944–46; see also: Carroll, Hunt, and Mitchell, Ill. Rpt. 1930; Ind. Rpt. 1940; Miss. Rpt. 64.
35. Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1939.
36. Hogan, Mo. Res. Bul. 167.
37. Bohstedt, Wis., Proc. 1955 Cornell Nutr. Conf.
38. Chapman et al., Iowa, Jour. Anim. Sci., 14, 1955, p. 1197.
39. Kirk and Crown, Fla. Bul. 372.
40. Robison, Ohio Bimo. Bul. 192.
41. Aubel, Hughes, and Lienhardt, Kan. Tech. Bul. 41; Aubel, Hughes, and Lienhardt, Kan., Jour. Agr. Res., 52, 1936, pp. 149–159; Mitchell, Carroll, and Hamilton, Ill. Bul. 434; see also: Ind. Rpt. 1940.
42. Aubel and Hughes, Kan. Rpt. 1936–38; Bethke, Edgington and Kick, Ohio, Jour. Agr. Res., 47, 1933, pp. 331–338.
43. Plumlee, Kennington, and Beeson, Ind., Jour. Anim. Sci., 14, 1955, p. 1220; Chapman, Kastelic, Ashton, and Catron, Iowa, Jour. Anim. Sci., 14, 1955, pp. 1073–1085; see also: Gobble, Miller, and Sherritt, Penn. Prog. Rpt. 121.
44. Shrewsbury and Vestal, Ind. Bul. 489 and Ind. Rpt. 1939; Mitchell et al., Ill. Bul. 434; Aubel, Kan. Cir. 207; Nebr. Rpt. 1939; Bohstedt, Wis. Cir. 297; Bohstedt et al., Wis. Buls. 440, 451.
45. Rice and Mitchell, Ill. Bul. 250; Vestal, Ind. Rpts. 1930, 1931; Evvard, Culbertson, and Hammond, Iowa, mimeo. rpts.; Kan. Rpt. 1923–24; Vinke and Bergstedt, Mont. Bul. 284; Loeffel, Nebr. Rpt. 1924; Hostetler et al., N.C. Rpts. 1929, 1930, 1932; Robison, Ohio Buls. 402, 417, 470, 532, 552; Ohio Spec. Cir. 17; Thompson, Okla. Rpts. 1926–30, 1930–32; Hale, Tex. Rpt. 1925; Morrison and Fargo, Wis. Buls. 396, 405; Sinclair and Sackville, Canada, Sci. Agr., 6, 1926, pp. 373–379; Paterson, West of Scotland Agr. Col., Bul. 102.
46. Grimes and Salmon, Ala. Bul. 222; Hughes, Cal. Rpt. 1928; Palmer, Del. Bul. 135; Rice and Mitchell, Ill. Bul. 250; Carroll, Hunt, and Mitchell, Ill. Rpt. 1930; Vestal, Ind. Rpt. 1927 and mimeo. rpts.; Evvard, Culbertson, and Hammond, Iowa Rpts. 1922, 1923, 1924; Evvard, Culbertson and Hammond, Iowa, Amer. Soc. Anim. Prod., Proc. 1922; Weaver, Mo. Bul. 256; Maynard, Goldberg, and Miller, N.Y. (Cornell) Memoir 86; Gray and Hostetler, Bul. N.C. Dept. Agr., 41, 1920, No. 6; Bohstedt, Robison, Bethke and Edgington, Ohio Bul. 395; Robison, Ohio Buls. 373, 552, and mimeo. rpt.; Thompson, Okla. Rpt. 1926–30; Hale, Tex. Rpt. 1926; May, Puerto Rico Sta., Rpt. 1929; Shaw, Jour. Min. Agr., Great Britain, 35, 1928, pp. 342–347; Evans, Jour. Agr. Sci., England, 20, 1930, pp. 117–125; Sheehy and Senior, Irish Free State, Dept. Agr. Jour., 30, 1931, No. 1, pp. 1–63; Crowther and Wright, Jour. Min. Agr., Great Britain, 39, 1932, pp. 201–207.
47. Culbertson, Hammond, and Thomas, Iowa, mimeo. rpt.; Robison, Ohio Buls. 470, 532.
48. Joseph, Mont. Bul. 169; Vinke and Bergstedt, Mont. Bul. 284; Mont. Rpts. 1925, 1929.
49. Hale, Texas Rpts. 1935, 1936, 1937, 1938, 1940.
50. Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1939.
51. Carroll, Mitchell, and Hunt, Ill., Jour. Agr. Res., 41, 1931, pp. 65–77; McClure and Mitchell, Ill., Jour. Agr. Res., 41, 1931,

pp. 79–87; Forbes et al., Penn., Jour. Agr. Res., 45, 1932, pp. 113–128; see also: Evvard and Culbertson, Iowa Res. Bul. 86; Robison, Ohio Buls. 402, 417.

52. Carroll, Hunt, and Mitchell, Ill. Rpt. 1929; Hamilton, Hunt, Mitchell, and Carroll, Ill., Jour. Agr. Res., 40, 1930, pp. 927–938; 47, 1933, pp. 543–563; Vestal and Doyle, Ind. Bul. 426; Anderson and Ferrin, Minn. Farm and Home Sci., 7, 1950, No. 2; Hanson and Meade, Nebr. Rpt. 63; Willman, McCay, and Gormel, N.Y. (Cornell) Rpts. 1930, 1931, 1932, 1933; Willman, McCay, and Morrison, N.Y., Amer. Soc. Anim. Prod., Proc. 1932; Moe, Craft, and Thompson, Okla. Rpt. 1932–34; Fargo, Beeson, and Deobald, Wis. Bul. 430; Fargo, Wis. Bul. 435; Schofield, Ontario Vet. Col., Canada, Rpt. 1929; Venn et al., England, Jour. Comp. Path. and Therap., 57, 1947, pp. 314–325.

53. Cunha et al., Fla. Cir. S-13; Speer, Catron, Homeyer, and Culbertson, Iowa, Jour. Anim. Sci., 11, 1952, pp. 112–117; Noland, Willman, and Morrison, N.Y., Jour. Anim. Sci., 10, 1951, pp. 875–884; Klosterman, Dinusson, Lasley, and Buchanan, N.D., Science, 112, 1950, pp. 168–169; Dinusson, Klosterman, Lasley, and Buchanan, N.D., Jour. Anim. Sci., 12, 1953, pp. 623–627; Robison, Ohio Bul. 725.

54. Robison, Ohio Bul. 705; Oldfield, Ore. Bul. 508.

55. Carroll, Hunt, and Mitchell, Ill. Rpts. 1928, 1929; Shrewsbury and Vestal, Ind. Bul. 489; Culbertson, Evvard, et al., Iowa Rpt. 1929 and mimeo. rpts.; Anderson and Ferrin, Minn. Farm and Home Sci., 7, 1950, No. 2; Bohstedt, Bethke, and Edgington, Ohio Bul. 395; Robison, Ohio Buls. 417, 488; Hart, Elvehjem, Bohstedt, and Fargo, Wis. Bul. 420.

56. Mitchell et al., Ill. Bul. 434; Shrewsbury and Vestal, Ind. Bul. 489; Evvard, Culbertson, et al., Iowa Leaflets 5, 12, 13, 17, and mimeo. rpts.; Culbertson, Iowa Rpt. 1931; Anderson, Culbertson, Evvard, and Hammond, Iowa, Amer. Soc. Anim. Prod., Proc. 1932; Robison, Ohio Buls. 488, 532; Thompson, Okla. Rpt. 1930–32 and mimeo. rpt.; Severson, N.D. Bimo. Bul., 5, 1943, No. 3; Longwell and Severson, N.D. Bimo. Bul. 6, 1944, No. 4; Morrison and Fargo, Wis. Bul. 405; Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1930.

57. Hughes, Cal., Jour. Agr. Res., 49, 1934, pp. 943–953; Hughes, Aubel, and Lienhardt, Kan. Tech. Bul. 23; Elder and Weaver, Mo. Bul. 370; Hostetler, Foster, and Halverson, N.C. Tech. Bul. 52; Hale, Tex., Jour. Heredity, 24, 1933, pp. 105–106; Morrison and Fargo, Wis. Buls. 339, 352; Albright and Fraser, Canada Dept. Agr. Pub. 736.

58. Hentges, Grummer, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 12, 1952, pp. 266–272; Sheffy, Drouliscos, Loosli, and Willman, N.Y., Jour. Anim. Sci., 13, 1954, p. 999; Texas Rpt. 1947–49; see also: Guilbert, Miller, and Hughes, Cal., Jour. Nutr., 13, 1937, pp. 543–564; Hale and Fraps, Texas Rpts. 1938, 1939, 1940, 1941, 1943; Dunlop, Jour. Agr. Sci., England, 25, 1935, pp. 217–230; Nordfeldt, Lantbr. Högsk. Ann., Upsala, Sweden, 12, 1944–45, pp. 204–221.

59. Parrish, Aubel, Hughes, and Wheat, Kan., Jour. Anim. Sci., 10, 1951, pp. 551–559.

60. Kernkamp, Minn. Tech. Bul. 31; Loeffel, Thalman, Olson, and Olson, Nebr. Res. Bul. 58; Maynard, Goldberg, and Miller, N.Y. (Cornell) Memoir 86; Bohstedt, Robison, Bethke, and Edgington, Ohio Bul. 395; Hart and Steenbock, Wis. Buls. 339, 352, 362.

61. Johnson and Palmer, Minn., Jour. Agr. Res., 63, 1941, pp. 639–648.

62. Crampton and Ashton, Canada, Sci. Agr., 26, 1946, pp. 16–24; see also: Johnson and Palmer, Minn., Jour. Agr. Res., 58, 1939, pp. 929–939; Bohstedt, Ross, Cunha, and Grummer, Wis. Bul. 460; Braude, Kon, and White, England, Jour. Comp. Path. and Therapeutics, 53, 1943, pp. 161–189.

63. Bohstedt et al., Wis. Buls. 455, 463, 466.

64. Loeffel, Thalman, Olson, and Olson, Nebr. Res. Bul. 58; Skelly, N.J. Bul. 661; Maynard, Goldberg, and Miller, N.Y. (Cornell) Memoir 86; Robison, Ohio Bul. 488; Bohstedt, Robison, Bethke, and Edgington, Ohio Bul. 395; Hart and Steenbock, Wis. Buls. 362, 388; Golding, Zilva, Drummond, and Coward, England, Biochem. Jour., 16, 1922, pp. 394–402; Zilva, Golding, Drummond, and Korenchevsky, Biochem. Jour., 18, 1924, pp. 872–880; Paterson, West of Scotland Agr. Col. Bul. 102; Sinclair, Canada, Sci. Agr., 13, 1922, pp. 489–502; Foot, Henry, and Kon, Jour. Agr. Sci., England, 29, 1939, pp. 142–163.

65. Willman and Morrison, N.Y. (Cornell) Bul. 730.

66. Willman and Morrison, N.Y. (Cornell) Bul. 836.

67. Robison, Ohio Bul. 488.

68. Pence, Miller, Dutcher, and Ziegler, Penn., Jour. Anim. Sci., 4, 1945, pp. 137–145; Ensminger, Heinemann, Cunha, and McCulloch, Wash. Bul. 468; Ellis and Madsen, U.S.D.A., Jour. Nutr., 27, 1944, pp. 253–262.

69. Davis, Freeman, and Madsen, Mich. Tech. Bul. 170; Rasmussen, Stafseth, Freeman, and Miller, Mich., Vet. Med., 39, 1944, pp. 421–423; Thorp et al., Mich., Jour. Anim. Sci., 8, 1949, p. 632; McMillen, Mich. Exten. Bul. 299; Burroughs, Edgington, Robison, and Bethke, Ohio, Jour. Nutr., 41, 1950, pp. 51–62.

70. Powick, Ellis, and Dale, U.S.D.A., Jour. Anim. Sci., 7, 1948, pp. 228–232; Miller, Penn. Bul. 502; Whitehair, Grummer, Bohstedt, and Phillips, Wis., Jour. Anim. Sci., 6, 1947, p. 492.

71. McMillen, Mich. Exten. Bul. 299; Burroughs, Edgington, Robison, and Bethke, Ohio Bul. 695.

72. McMillen, Luecke, and Thorp, Mich., Jour. Anim. Sci., 7, 1948, p. 529; Luecke, Hoefer, and Thorp, Mich., Jour. Anim. Sci., 11, 1952, pp. 238–243; 12, 1953, pp. 605–610; Meade, Nebr. Swine Prog. Rpt. 316.

73. Robison, Ohio Res. Bul. 729; Ohio Anim. Sci. Mimeo. Ser. 92.

74. Anderson and Hogan, Mo., Jour. Anim. Sci., 9, 1950, p. 646 and mimeo. rpt.; Robison, Ohio Res. Bul. 729.

75. Noland, Proc. 1951 Ark. Formula Feed Conf.; Gard et al., Ill., Jour. Anim. Sci., 14, 1955, pp. 532–544; Anderson and Hogan, Mo., Jour. Anim. Sci., 9, 1950, pp. 163–169; Luther and Brown, Jour. Anim. Sci., 10,

1951, p. 1055; Reynolds et al., Jour. Anim. Sci., 12, 1953, p. 929.
76. Lehrer and Wiese, Id. Res. Bul. 21.
77. Briggs and Beeson, Ind., Jour. Anim. Sci., 10, 1951, pp. 813–819.
78. McMillen, Luecke, and Thorp, Mich., Jour. Anim. Sci., 8, 1949, pp. 518–523.
79. Hanson and Ferrin, Minn. Mimeo. Rpt. H-104; see also: Whitehair and Hillier, Okla. Misc. Pub. MP-27.
80. Luecke et al., Mich. Tech. Bul. 211.
81. Fairbanks, Burroughs, Carroll, and Hamilton, Ill. Rpt. 1938; Shrewsbury, Vestal, and Hague, Ind., Jour. Agr. Res., 44, 1932, pp. 267–274; Culbertson, Iowa Rpt. 1932; Culbertson and Thomas, Iowa Rpt. 1933; Brown and Edwards, Mich. Quar. Bul., 7, 1924, No. 1; Edwards and Brown, Mich. Quar. Bul., 8, 1925, No. 2; Weaver, Mo. Bul. 228; Loeffel, Nebr. Rpt. 1937; Robison, Ohio Res. Bul. 699; Thompson, Okla. Bul. 165; Wash. Bul. 187; Livesay and Stillwell, West Va. Bul. 213; Morrison, Fargo, and Thomas, Wis. Bul. 488.
82. Robison, Ohio Res. Bul. 699.
83. Bohstedt, Grummer, and Ross, Wis., Jour. Anim. Sci., 2, 1943, p. 373.
84. Noland, Willman, and Morrison, N.Y., Jour. Anim. Sci., 10, 1951, pp. 875–884, and unpublished data.
85. Willman, Morrison, McCay, and Loosli, N.Y. (Cornell) Rpts. 1943, 1944; Robison, Ohio, information to the author; Cunha, Warwick, and Ensminger, Wash. Mimeo. Cir. 29; Ellis, Zeller, and King, U.S.D.A., Jour. Anim. Sci., 1, 1942, p. 358; see also: Lehrer and Keith, Id. Bul. 295; Aubel, Kan. Cir. 258.
86. Morrison, Bohstedt, and Fargo, Wis. Buls. 323, 339, 352.
87. Morrison, Bohstedt, and Fargo, Wis. Spec. Cir., Dec. 1922; Morrison and Fargo, Wis. Bul. 352.
88. Morrison and Fargo, Wis. Bul. 352; Fargo and Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1929; Evvard, Culbertson, Hammond, et al., Iowa, mimeo. rpts.; Johnson, Minn., mimeo. rpt.; Robison, Ohio Bul. 488; Kuhlman and Wilson, S.D. Bul. 216.
89. Aubel and Connell, Kan. Rpt. 1930–32; Aubel, Kan. Rpt. 1944–46; Robison, Ohio Bul. 488; Kuhlman and Wilson, S.D. Bul. 216; Morrison and Fargo, Wis. Bul. 352; Fargo and Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1929.
90. Morrison and Fargo, Wis. Bul. 396; Loeffel, Nebr. Rpt. 1932; Nebr. Rpt. 1940; see also: Weaver, Mo., mimeo. rpt.
91. Morrison and Fargo, Wis. Bul. 352; Fargo and Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1929.
92. Vestal, Ind. Bul. 508.
93. Carroll, Mitchell, Hamilton, and Garrigus, Ill., mimeo. rpt.; Loeffel, Nebr., mimeo. rpt.; Robison, Ohio Bul. 659; Wright, S.D. Bul. 445; Bohstedt, Fargo, and Hayward, Wis. Bul. 430 and information to the author.
94. Morrison, Fargo, and Thomas, Wis. Bul. 388; Fargo and Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1929.
95. Tomhave, Del. Bul. 167; Vestal, Ind. Bul. 508.
96. Bohstedt, Fairbanks, and Loeffel, National Research Council, Rpt. No. 6 of Committee on Animal Nutrition, 1942.
97. Krider, Terrill, and Dyer, Ill. Mimeo. Rpt. A.S. 155; Robison, Ohio Res. Bul. 699; see also: Dinusson, Klosterman, Lasley, and Buchanan, N.D., Jour. Anim. Sci., 12, 1953, pp. 623–627.
98. Vestal, Ind., mimeo. rpt.; Weaver, Mo. Bul. 490.
99. Willman and Morrison, N.Y. (Cornell) Bul. 730; Hostetler, N.C. Rpts. 1926, 1927, 1929, 1930; Hostetler and Foster, N.C., mimeo. rpts.; Godbey and Starkey, S.C. Bul. 281.
100. Vestal, Ind., mimeo. rpts.; Culbertson, Thomas, Hammond, and Beard, Iowa, mimeo. rpt.; Weaver, Mo., mimeo. rpt.; Loeffel, Nebr. Rpt. 1934; Hostetler, N.C. Bul. 259; Godbey and Durant, S.C. Bul. 234; Godbey and Starkey, S.C. Bul. 281; Duncan and Hazlewood, Tenn. Rpt. 1944.
101. Morrison and Willman, N.Y. (Cornell) Bul. 836.
102. Martin, Ark., mimeo. rpt.; Vestal, Ind., mimeo. rpts.; Evvard, Culbertson, et al., Iowa, mimeo. rpt.; Aubel and Connell, Kan., mimeo. rpt.; Loeffel, Nebr. Rpt. 1935; Wilson and Wright, S.D. Bul. 262; Morrison and Fargo, Wis. Bul. 323; Fargo and Bohstedt, Wis., Amer. Soc. Anim. Prod., Proc. 1929.
103. Ky. Rpts. 1950, 1951, 1952.
104. For a review of the experiments on antibiotics in swine feeding, see: Braude, Wallace, and Cunha, Fla., The Value of Antibiotics in the Nutrition of Swine, Antibiotics and Chemotherapy, 3, 1953, pp. 271–291; see also: Braude, Kon, and Porter, England, Nutr. Abstr. and Reviews, 23, 1953, pp. 473–495; Stokstad, Physiol. Reviews, 34, 1954, pp. 25–51.
105. Becker, Terrill, and Notzold, Ill., Jour. Anim. Sci., 14, 1955, pp. 492–498; Aubel, Kan. Cir. 308; Wahlstrom, S.D. Bul. 446; Shefchick et al., Wis. Bul. 492.
106. Speer, Catron, Ashton, and Culbertson, Iowa, Jour. Anim. Sci., 14, 1954, p. 1012; Aubel, Kan. Cirs. 273, 283; Ky. Rpts. 1952, 1953; Hanson, Ferrin, and Aunan, Minn. Mimeo. Rpt. H-103; Lasley, Tribble, and Hogan, Mo. Res. Bul. 543; Baker, Brinegar, Blum, and Clawson, Nebr., Jour. Anim. Sci., 10, 1951, p. 1035; Robison, Ohio Anim. Sci. Mimeo. Ser. 86, 96; Chamberlain and Lidvall, Tenn. Farm and Home Sci. No. 10.
107. Wallace et al., Fla., Jour. Anim. Sci., 12, 1953, pp. 316–321; Lehrer, Pharris, Harvey, and Keith, Id., Jour. Anim. Sci., 12, 1953, pp. 304–309; Terrill, Becker, Adams, and Meade, Ill., Jour. Anim. Sci., 11, 1952, pp. 84–91; Vestal, Ind. Mimeo. Rpt. A.H. 65; Aubel, Kan. Cirs. 283, 297; Ky. Rpts. 1951, 1952; Hanson, Ferrin, Anderson, and Aunan, Minn., Jour. Anim. Sci., 14, 1955, pp. 30–42; Wahlstrom, S.D. Bul. 446; Burnside, Grummer, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 12, 1953, pp. 828–835.
108. Wallace et al., Fla., Jour. Anim. Sci., 13, 1954, pp. 177–183; Catron et al., Iowa, Jour. Anim. Sci., 11, 1952, pp. 221–232; Jensen et al., Iowa, Jour. Anim. Sci., 14, 1955, pp. 69–81; Wahlstrom, S.D. Bul. 446; Burnside, Grummer, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 10, 1951, pp. 1042–1043; Hironaka and Bowland, Canada, Jour. Anim. Sci., 34, 1954, pp. 343–351.
109. Ashton et al., Iowa, Jour. Anim. Sci., 14, 1955, pp. 82–93; Hall, Me. Farm Res., 1, 1953, No. 3; Wingert, Aunan, Ferrin, and Han-

son, Minn., Jour. Anim. Sci., 14, 1955, p. 1234; Huang and McCay, N.Y., Jour. Nutr., 50, 1953, pp. 129–139; Clawson, Sheffy, and Reid, N.Y., Jour. Anim. Sci., 14, 1955, pp. 1122–1132; Robison, Kunkle, and Cahill, Ohio, Jour. Anim. Sci., 11, 1952, p. 752; Wilson et al., Wis., Jour. Anim. Sci., 12, 1953, pp. 290–296; Barber, Braude, Kon, and Mitchell, England, Brit. Jour. Nutr., 7, 1953, pp. 306–319.

110. Bowland, Beacom, and McElroy, Canada, Jour. Anim. Sci., 10, 1951, pp. 629–637; Hironaka and Bowland, Canadian Jour. Agr. Sci., 34, 1954, pp. 343–351.

111. Wallace and Milicevic, Fla. Rpt. 1953; Terrill et al., Ill. Mimeo. Rpt. A.S. 323; Perry, Thrasher, and Beeson, Ind., Jour. Anim. Sci., 12, 1953, pp. 824–827; Swenson et al., Kan., Jour. Anim. Sci., 13, 1954, p. 1032; Hanson and Ferrin, Minn., mimeo. rpt.; Lasley, Tribble, Case, and Penrod, Mo., Jour. Anim. Sci., 12, 1953, p. 923; Clawson, Sheffy, and Willman, N.Y., Jour. Anim. Sci., 12, 1953, p. 911; see also: Noland, Tucker, and Stephenson, Ark. Rpt. Ser. No. 34.

112. Hanson and Ferrin, Minn., Jour. Anim. Sci., 11, 1952, p. 763.

113. Stevenson, Ellis, and Davey, U.S.D.A., Jour. Anim. Sci., 13, 1954, pp. 1000–1001; see also: Terrill et al., Ill., Mimeo. Rpt. A.S. 268.

114. Sheffy, Grummer, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 11, 1952, pp. 97–102; Reynolds, Pendergrass, and Luther, Jour. Anim. Sci., 13, 1954, p. 997.

115. Ky. Rpt. 1951; Wallace, Fla., Jour. Anim. Sci., 14, 1955, p. 1225; Vestal et al., Ind. Rpt. 66; Catron et al., Iowa Rpt. 1951–53; Carpenter and Larson, Minn., Jour. Anim. Sci., 12, 1953, pp. 812–818; DePape, Burkitt, and Flower, Mont., Jour. Anim. Sci., 12, 1953, pp. 77–83; Heidebrecht, Ross, MacVicar, and Whitehair, Okla., Jour. Anim. Sci., 9, 1950, pp. 658–659; Fowler and Robertson, Tex., Jour. Anim. Sci., 13, 1954, pp. 949–954; Stevenson, Ellis, and Davey, U.S.D.A., Jour. Anim. Sci., 13, 1954, pp. 1000–1001; Davey, Green, and Stevenson, U.S.D.A., Jour. Anim. Sci., 14, 1955, pp. 507–512; VanPoucke, Hanson, Peeler, and Rodgers, Jour. Anim. Sci., 9, 1950, pp. 670–671.

116. Wallace, Ney, and Cunha, Fla., Jour. Anim. Sci., 10, 1951, pp. 1066–1067; Schendel and Johnson, Ill., Jour. Anim. Sci., 14, 1955, pp. 19–23; Hanson et al., Minn., Jour. Anim. Sci., 14, 1955, pp. 313–324, 525–531; Dinusson, Klosterman, Holm, and Buchanan, N.D. Bimo. Bul., 14, 1952, No. 5; Whitehair and Hillier, Okla. Misc. Pub. MP-27; Bridges, Hale, Kunkel, and Lyman, Tex., Jour. Anim. Sci., 13, 1954, pp. 912–917.

117. Wallace, Combs, and Cunha, Fla. Rpt. 1953; Dyer, Davis, and Cullison, Ga., Jour. Anim. Sci., 11, 1952, p. 760; Schendel and Johnson, Ill., Jour. Anim. Sci., 14, 1955, pp. 19–33; Perry, Beeson, and Vosteen, Ind., Jour. Anim. Sci., 12, 1953, pp. 310–315; Beeson, Perry, and Reynolds, Ind., Jour. Anim. Sci., 12, 1953, pp. 619–622; Catron, Iowa Farm Sci., 8, 1954, No. 7; Luecke, Hoeffer, and Thorp, Mich. Quar. Bul., 34, 1952, No. 3; Sheffy, Clawson, and Willman, N.Y., Jour. Anim. Sci., 12, 1953, p. 931; Day, Anderson, Johnson, and Lewis, West Va., Jour. Anim. Sci., 12, 1953, pp. 944–945; Williams, Owen, Elliott, and Jukes, Jour. Anim. Sci., 11, 1952, pp. 781–782.

118. Perry, Beeson, and Andrews, Ind., Jour. Anim. Sci., 13, 1954, pp. 995–996; Taylor, Catron, Ashton, and Burroughs, Iowa, Jour. Anim. Sci., 14, 1955, p. 1258; Murfree, Tenn. Farm and Home Sci., Prog. Rpt. 13.

119. Sleeth, Fla., Jour. Anim. Sci., 12, 1953, pp. 322–330; Tenn. Rpt. 1951.

120. Winchester and Sykes, in Report of Committee on Animal Nutrition of National Research Council on "Hormonal Relationships and Applications in the Production of Meats, Milk, and Eggs," National Research Council Pub. 266, 1953. Numerous references to publications on this subject are given in this report.

121. Evvard, Iowa Res. Bul. 118.

122. Evvard, Wallace, and Culbertson, Iowa Bul. 245; Garner and Sanders, Jour. Agr. Sci., England, 27, 1937, pp. 638–643.

123. Culbertson, Evvard, et al., Iowa Leaflet 18; Ferrin and McCarty, Minn., mimeo. rpt.

124. Ind. Rpt. 1945; Altman, Ashton, Catron, and Culbertson, Iowa Farm Sci., 8, 1954, No. 7; Nebr. Rpt. 1937.

125. Wilson and Wahlstrom, S.D. Farm and Home Res., 4, 1953, No. 3.

126. Atkinson and Klein, U.S.D.A. Tech. Bul. 894.

127. Cummings and Winters, Minn. Tech. Bul. 195; Lasley et al., Mo. Buls. 584, 621; see also: Burroughs and Carroll, Ill., Amer. Soc. Anim. Prod., Proc. 1939; Freeman, Mich. Quar. Bul. 17, 1935, No. 3; Gregory and Dickerson, Mo. Res. Bul. 493; Warren and Dickerson, Mo. Res. Bul. 511; Morrison, Willman and St. Pierre, N.Y. (Cornell) Rpt. 1934; St. Pierre, Morrison, and Willman, N.Y., Amer. Soc. Anim. Prod., Proc. 1934; Robison, Ohio Bul. 664; Lindgren, Oliver, and Potter, Ore. Bul. 297; Ellis and Zeller, U.S.D.A. Tech. Bul. 413.

128. Morrison, Willman, and St. Pierre, N.Y. (Cornell) Rpt. 1934; St. Pierre, Morrison, and Willman, N.Y., Amer. Soc. Anim. Prod., Proc. 1934; see also: Freeman, Mich. Quar. Bul., 17, 1935, No. 3; Robison, Ohio Monthly Buls. 59–60; Ellis and Zeller, U.S.D.A. Tech. Bul. 413.

129. Ferrin and McCarty, Minn. Bul. 248; Freeman, Mich. Quar. Bul., 17, 1935, No. 3; St. Pierre, Morrison, and Willman, N.Y., Amer. Soc. Anim. Prod., Proc. 1934; Hostetler, N.C. Rpt. 1931; S.D. Rpt. 1926.

130. Robison, Ohio Mo. Buls. 59–60.

131. Merkel et al., Wis. Bul. 511.

132. Whatley, Gard, Whiteman, and Hillier, Okla. Bul. B-398.

133. Singletary, Bertrand, Crown, and Damon, La. Rpts. 1952, 1953.

134. Vestal, Ind. Bul. 279; Evvard, Iowa, mimeo. rpts.; Bell, Winchester, and Marston, Kan. Cir. 98; Edwards, Mich. Spec. Bul. 199; Ferrin and McCarty, Minn. Bul. 248; Fletcher, Miss. Farm. Res., 17, 1954, No. 2; Weaver, Mo. Bul. 247 and information to the author; Robison, Ohio, Amer. Soc. Anim. Prod., Proc. 1931; Oliver, Ore. Cir. of Inf. 490; Morrison, Bohstedt, and Fargo, Wis., mimeo. rpts. and unpublished data.

135. Lloyd and Young, Ind. Bul. 310.

136. Smith, Cole, and Hobbs, Tenn. Farm and Home Sci., Prog. Rpt. 3.

137. Vaughan, Joseph, and Vinke, Mont. Rpts.

1925, 1927, 1929; Arnett and Joseph, Mont. Bul. 128; Joseph, Mont. Bul. 236; Headley, Nev. Bul. 125; Ore. Rpt. 1920–1922; S.D. Rpt. 1928; Schaefer and Smith, Wash. Bul. 198; Hansen, U.S.D.A. Cir. 204; Russell, U.S.D.A. Tech. Bul. 17.

138. Dvorachek and Sandhouse, Ark. Bul. 191; Rice and Liable, Ill., information to the author; McCampbell, Kan. Cir. 78; Weaver, Mo. Bul. 144 and information to the author; Snyder, Nebr. Bul. 214; Loeffel, Nebr., mimeo. rpts.; Robison, Ohio Bul. 355; Ashbrook and Gongwer, U.S.D.A. Farmers' Bul. 906.

139. Evvard, Iowa, Corn Belt Meat Producers' Assoc., Rpt. 1914, and mimeo. rpt.; Snyder, Nebr. Bul. 165; Robison, Ohio Buls. 343, 355.

140. Culbertson and Thomas, Iowa Rpt. 1933; Edwards and Brown, Mich. Quar. Bul., 8, 1925, No. 2.

141. Thompson and Voorhies, Cal. Bul. 342; Vestal, Ind., mimeo. rpt.; Culbertson and Thomas, Iowa Rpt. 1933; Aubel and Alexander, Kan. Cir. 187; Ky. Rpt. 1932; Ferrin and Johnson, Minn., mimeo. rpt.; Weaver, Mo. Bul. 163; Thompson, Okla. Rpt. 1936–38; Penn. Bul. 293; Wyo. Rpt. 1921; Garrido, Philippine Agr., 19, 1930, pp. 397–409.

142. Me. State Col. Agr., Rpt. Trustees, 1876; Ontario School of Agr., Rpt. 1876; Kan. Agr. Col. Rpt. 1885; Iowa Agr. Col. Rpt. 1891; Wis. Rpt. 1886.

143. Lehrer and Keith, Id. Bul. 295; Ill. Rpt. 1947–48; Hoefer, Luecke, and Thorp, Mich., Jour. Anim. Sci., 11, 1952, p. 765; Thomas and Flower, Mont., Jour. Anim. Sci., 12, 1953, p. 933; Bohman, Kidwell, and McCormick, Nev., Jour. Anim. Sci., 12, 1953, pp. 876–880; Dinusson, Light, Bolin, and Buchanan, N.D. Bimo. Bul., 15, 1953, No. 4; N.D. Bul. 396; Steffen, Utah Farm and Home Sci., 14, 1953, No. 4; Schneider and Brugman, Wash. Stas. Cir. 115.

144. Wilford, Ky. Rpts. 1928, 1929, Amer. Soc. Anim. Prod., Proc. 1930.

145. Anderson and Marston, Kan. Cir. 112.

146. Heitman and Hughes, Cal., Jour. Anim. Sci., 8, 1949, pp. 171–181; Heitman, Hughes, and Kelly, Cal. and U.S.D.A., Jour. Anim. Sci., 10, 1951, pp. 908–915; Heitman, Kelly, and Bond, Cal. and U.S.D.A., Jour. Anim. Sci., 13, 1954, p. 1021.

147. Tidwell and Fletcher, Miss., Jour. Anim. Sci., 10, 1951, pp. 523–532; Miss. Rpt. 64.

148. Hale, Tex. Rpts. 1938, 1939, 1940, 1941.

149. Smith et al., Tenn., information to the author.

150. Morrison, Bohstedt, and Scott, Wis. Sta., mimeo. rpts.

151. Edwards and Freeman, Mich. Rpt. 1928–1930.

152. Grisdale, Ottawa, Canada, Expt. Farms, Rpt. 1904.

153. Shelton, Kan. Agr. Col., Rpt. Prof. Agr. 1883.

154. Vestal, Ind. Bul. 413; Anderson and Marston, Kan. Cir. 118; Hogan, Mo. Res. Bul. 168.

155. Vestal, Barrick, and Quackenbush, Ind. Rpts. 1947, 1948, 1949.

156. Morrison, Bohstedt, and Fargo, Wis., unpublished data; Comstock, Winters, and Cummings, Minn., Jour. Anim. Sci., 3, 1944, pp. 120–128.

157. Bull and Olson, Ill. Rpt. 1931; Scott, Ind. Bul. 340; Ind. Rpt. 1927; Robison, Ohio Bul. 497; Mohler, U.S.D.A., Ann. Rpt. Chief of Bur. of Anim. Indus., 1928; Park, National Provisioner, 82, 1930, p. 25; Warner, Ellis, and Howe, U.S.D.A., Jour. Agr. Res., 48, 1934, pp. 251–252.

158. Mitchell, Hamilton, Bull, and Longwell, Ill. Rpt. 1927.

159. Grummer and Bohstedt, Wis. Bul. 489.

160. Johnson and Wright, S.D. Bul. 386.

161. Foster and Merrill, Utah Bul. 70.

162. Whatley, Stephens, and Teufel, Okla. Misc. Pub. MP-34; Whatley, DePape, Walters, and Chambers, Okla. Misc. Pub. MP-34; Robison, Ohio, mimeo. rpt.

163. Lush, Iowa Res. Bul. 204.

164. Bjorka, U.S.D.A. Tech. Bul. 621

165. Henning and Stout, Ohio Bul. 505.

166. Hankins and Ellis, U.S.D.A. Bul. 1407; Hankins, Ellis, and Zeller, U.S.D.A. Bul. 1492; Ellis, U.S.D.A. Tech. Bul. 368; Ellis and Hankins, U.S.D.A., Jour. Biol. Chem., 66, 1925, pp. 101–122; Martin, Ark. Buls. 246, 268; Tomhave and Mumford, Del. Bul. 179; Edwards, Ga. Rpt. 1927; Bull, Carroll, et al., Ill. Bul. 366; Bull, Ill. Rpt. 1933; Scott, Ind. Bul. 340; Vestal and Shrewsbury, Ind. Rpts. 1938, 1939; Culbertson et al., Iowa Rpts. 1936, 1937, 1938, 1939, 1940 (Part 1); Halverson and Sherwood, N.C. Tech. Bul. 61; Hostetler and Halverson, N.C. Tech. Bul. 63; Blumer et al., N.C., Jour. Anim. Sci., 13, 1954, p. 967; Robison, Ohio Buls. 452, 516, 664; Ore. Rpt. 1940; Godbey, S.C. Rpt. 1930; Wilson, S.D. Rpts. 1931, 1933; Jacob, Tenn. Rpt. 1930.

167. Hostetler, Halverson, and Sherwood, N.C. Tech. Bul. 61.

168. Crampton, Ashton, and Lloyd, Canada, Jour. Anim. Sci., 13, 1954, pp. 321–331.

CHAPTER XXXV

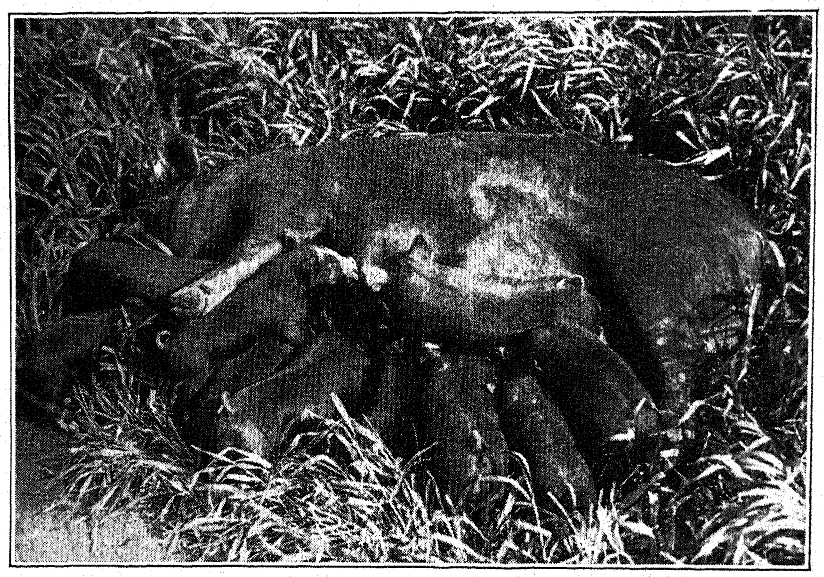
FEEDING AND CARE OF SWINE

I. Pasture for Swine

1449. Importance of good pasture for swine.—When plenty of good pasture is provided for swine throughout the growing season, pork can usually be produced at much lower cost than when swine are kept in dry lots. The importance of pasture in keeping swine thrifty and preventing nutritional deficiencies has been emphasized in the previous chapter. (1383)

Not only does good pasturage furnish digestible nutrients at low cost, but still more important, it provides insurance against any deficiency of vitamins. In addition, the best pasture crops are rich in protein of fairly good quality and they are high in calcium.

Good pasture is especially important for brood sows and boars and for young pigs. Sows that are raised entirely in dry lot are apt to produce unsatisfactory litters, even when fed rations that would be satisfactory if the sows had been on pasture part of the time. (1384) Similarly, fall pigs do better during the winter when they get a good start on pasture before they are confined to dry lot.



Every Litter Needs Good Pasture

Nothing is more important in swine raising than furnishing good pasture just as early as possible for the brood sows and their litters.

Another advantage of keeping swine on pasture is that it builds up soil fertility, because the manure is well distributed over the field. When swine are kept in small unpaved hog lots, often but little use is made of the manure and much fertility is wasted.

Because of the many advantages and the great economy of pasture for swine, the largest net returns can usually

be secured only when an abundance of first-rate pasture is provided during as much of the year as is possible.

In the southern states good pasture can even be provided during all or most of the winter. In the North there should be good pasture for the brood sows and their litters in the spring; for the growing and fattening pigs from weaning time until market or until frost kills the crop; for the brood sows and boar throughout the growing season; and especially for any fall pigs.

It must be borne in mind that good pasture means not only pasture which furnishes plenty of palatable feed, but also pasture that is not contaminated with round worms and other swine parasites. It is emphasized later in this chapter that to prevent serious trouble from internal parasites, a system of swine sanitation should be followed, in which pigs are on clean pasture throughout the season, instead of being kept in filthy hog lots. (1491)

Occasionally, statements are made that pigs fattened on pasture do not yield as desirable carcasses as those finished in dry lot. Experiments have shown, however, that when pigs are properly fattened on pasture by feeding a liberal amount of grain in a balanced ration, the carcasses are fully equal to those from dry-lot feeding.[1]

Sometimes a plan of producing pork is advocated in which no pasture whatsoever is used, but instead all swine are confined to inside pens with access to outside paved lots. As has been emphasized in the preceding chapter, it is difficult to prevent nutritional deficiencies when swine never have access to pasture. (1384) The use of pasture, especially for brood sows and young pigs, therefore seems decidedly preferable to keeping swine continuously on concrete. When pigs are fed in dry-lot from weaning time to market, it is important that they first get a good start on first-rate pasture.

1450. Various pasture crops.—The choice of pasture crops for any particular section will depend primarily on the soil and climatic conditions. Those pasture crops are best for any locality which give high yields of palatable, nutritious forage over a long season, at a low cost for growing the crop. Detailed information is given in Chapter XIII concerning pastures and pasture improvement and management. The many different crops suitable for pasture are discussed in other chapters of Part II.

Wherever they thrive either alfalfa or Ladino clover ranks first as a pasture crop for swine. They provide excellent forage over a longer season than most other forage crops, and are very rich in protein, calcium and vitamins. A mixture of these legumes with a moderate amount of grass may be equal to the legume alone, and endure longer in the pasture.

Red clover also is excellent for swine pasture, but generally provides less feed in midsummer. Alsike clover is suitable for soils too wet or too acid for red clover. White clover is important in mixed and permanent pastures, for it greatly improves grass pasture. Sweet clover may be used in districts where it thrives better than alfalfa or red clover, but in other sections it is decidedly inferior to them.

Lespedeza is one of the most valuable pasture crops in the South. Soybeans furnish good forage for only a rather short season and are therefore less valuable for pasture than alfalfa, Ladino clover, or red clover, where the latter thrive. Cowpeas are a useful pasture crop for poor soil in the South, but are excelled by soybeans on good soil.

Rape is the best single annual pasture crop for swine where it thrives, and is nearly equal to alfalfa or red clover in value per acre. If not pastured too heavily, early-sown rape will furnish good forage from early summer until late in the fall, for the plants are not killed by ordinary frosts. In the northern-most states a combination of rape with oats or barley, or with oats and peas, may be slightly superior to rape alone.

Permanent grass pasture, such as bluegrass, furnishes good forage in spring and in autumn, but often supplies little feed in mid-summer. Other pasture should therefore be provided for this season. Bromegrass and orchard grass

furnish pasture over a longer season than bluegrass, and much more forage in midsummer. However, they are more valuable when combined with a suitable legume.

Pigs on grass pasture require a somewhat greater amount of protein supplement than those on such protein-rich pasture crops as alfalfa, clover, or rape. Sudan grass is a satisfactory pasture crop where the climate is too dry for better pastures.

Winter cereals provide excellent late fall and early spring pasture in the northern states. In the South first-rate pasture can be furnished during much of the winter by winter cereals or by crimson clover and rye grass.

1451. Essentials on pasture.—Swine on pasture should be provided with an abundant supply of fresh water and with shade. Salt should always be furnished, except possibly when tankage, meat scrap, or fish meal is fed as the only supplement. (1398)

It is often necessary to ring hogs to prevent serious damage to a pasture by rooting. Swine that are fed well-balanced rations are much less apt to root than are dissatisfied hogs fed an inefficient ration, but the feeding of a good ration is no insurance against rooting.

Sometimes it is not necessary to ring spring pigs which will be sold in the fall at the close of the pasture season, for they are less apt to root than are older hogs. However, the pasture lots must be watched closely, and if the pigs start to root badly, it will be necessary to ring them at once, especially if they are on a permanent pasture, such as alfalfa or bluegrass. Even if fed good rations, pigs are apt to begin rooting after hard summer or fall rains, in order to get the earth worms which then come close to the surface of the ground. This is not surprising, since in its natural state the hog gained its living largely by rooting. On annual crops, such as rape, it is not usually necessary to ring pigs if they are fed well-balanced rations.

1452. Value of pasture in pork production.—The importance of good pasture in increasing the net returns from swine is well shown by 1,419 yearly cost accounting records of pork production on Minnesota farms.[2] On farms where swine had good pasture (legumes, rape, or rape combined with small grain), an average of only 486 lbs. of feed (including that eaten by the breeding herd) were required per 100 lbs. of hogs marketed. On farms where the swine had no pasture, the feed requirement was 522 lbs., and on farms where the only swine pasture was timothy or bluegrass, it was 509 lbs.

The difference was even greater in the net return over cost of feed per 100 lbs. of hogs marketed. This was $1.70 per 100 lbs. on the farms with good swine pasture, but only $1.22 on the farms with no swine pasture and $1.37 for those with grass pasture for swine. The net return over cost of feed was therefore 39 per cent greater where good pasture was provided than where the hogs were kept in dry lot.

1453. Pasture vs. dry lot for growing and fattening pigs.—Though good pasture is most important for brood sows and young pigs, numerous experiments have shown that it also has a high value for growing and fattening pigs, even those that have gotten a good start on pasture.

The advantage from pasture-feeding in comparison with feeding an efficient ration in dry lot is shown by the results secured in 40 experiments.[3] In each trial one lot of pigs was full-fed corn and a suitable supplement on good pasture from shortly after weaning until the pigs reached market weight. Another lot was fed in dry lot on corn and an efficient modern supplement which contained ground legume hay.

The pigs on pasture gained 1.43 lbs. per head daily and required 359 lbs. concentrates per 100 lbs. gain. Those fed the efficient ration in dry lot gained nearly as rapidly (1.40 lbs. a day), but they consumed 399 lbs. of feed per 100 lbs. gain. Thus, 40 lbs. more concentrates, or 11 per cent more, were required per 100 lbs. gain by the dry-lot pigs. The greater part of this additional feed was expensive protein supplement, for pigs

in dry lot need much more protein supplement than do pigs on good pasture.

In the earlier experiments, comparing pasture-feeding with dry-lot feeding, there was a considerably greater difference in the results. This was because the dry-lot pigs were fed such a ration as corn and tankage. As has been emphasized in the preceding chapter, this sort of ration is much less satisfactory for pigs in dry lot than efficient modern rations that include legume hay and a suitable combination of protein supplements. (**1418–1420**)

The opinion is sometimes held that pigs which have been raised to a weight of 100 to 150 lbs. on pasture will make more rapid and economical gains during the final fattening period if they are finished in dry lot, where they get less exercise. However, in New York experiments conducted during 6 summers to study this method, the gains were about as rapid and slightly more economical when the pigs were kept on good pasture until they were ready for market.[4] Keeping pigs on pasture until they are ready for market saves the labor of cleaning out manure from the hog barn.

When pigs are full-fed grain and supplement on good pasture, an acre of pasture should provide enough forage for 15 to 20 pigs from weaning time to the end of the pasture season. Pigs fed only a limited amount of concentrates need more pasture.

If pasture feeding is compared with an efficient dry-lot ration, such as corn and a trio-type supplemental mixture, an acre of good pasture for full-fed pigs will usually save 300 to 500 lbs. grain and 450 to 700 lbs. supplement.

The stand of alfalfa or Ladino clover is injured by continuous close grazing. Therefore, if one wishes to maintain the stand for several years, it is best to provide a sufficient area of these crops so that considerable forage will grow up to be cut for hay once or twice during the season. Alfalfa should carry at least 8 to 10 full-fed pigs per acre throughout the summer with no danger to the stand. (**466**)

II. The Breeding Herd

1454. Selecting the brood sows and boar.—For efficiency in pork production, it is necessary, first of all, to have breeding stock of the right kind. The sows and boar should be of the proper type and conformation to produce finished hogs that meet the market demands. Also, they should be selected from strains of swine that excel in rapidity and economy of gains. Fully as important as these essentials, is the prolificacy of the sows and their ability to raise good-sized litters of pigs.

It costs nearly as much to feed and care for a sow that raises a litter of only 3 to 5 pigs to weaning age as a sow that raises 7 or 8 pigs or more. Therefore, to reduce the cost per pig at weaning time, the sows must have large litters of thrifty pigs and also be good mothers, so they will raise nearly all of the pigs that they farrow.

To build up an efficient herd the pigs should be ear-notched or otherwise marked, and breeding records should be kept. The sows that have proven to be unproductive can then be culled from the herd and replaced by gilts from the best sows. These will be the ones that are good mothers and raise large litters of pigs of good type which make rapid gains in weight. Such pigs produce pork much more economically than do those which gain slowly.

1455. Proper feed and care necessary for profits.—In securing a good profit from hogs nothing is of greater importance than proper feeding and care of the brood sows and boars. Every year thousands of farmers are grievously disappointed at farrowing time by seeing their possible profits vanish when the sows produce unsatisfactory litters.

Either the number of pigs in the litters is small, or the pigs are so weak that many die or survive only to become unprofitable runts. In most cases such results are due to lack of proper feed and care. Yet the needs of brood sows are relatively simple and easily met.

The most important essentials in the feeding and care of brood sows are: (1)

Efficient rations that fully meet their nutrient requirements; (2) rations that are laxative, instead of constipating; (3) the right amount of feed—not too much or the sows will get too fat; (4) plenty of exercise; (5) comfortable, sanitary quarters, with guard rails or pig brooders in the pens to protect the young pigs; (6) freedom from lice and worms.

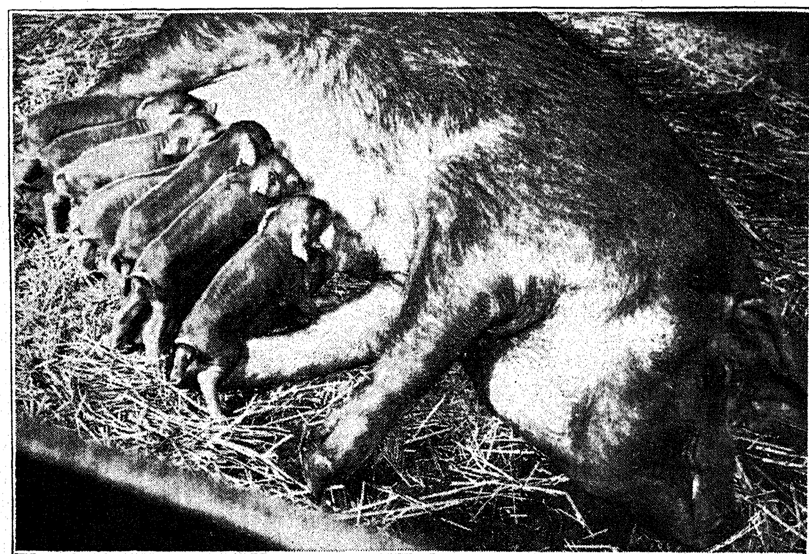
1456. Rations for brood sows.—The nutrient requirements of brood sows have been discussed in detail in the previous chapter. Further information is given in articles which follow concerning their special needs for protein, minerals, vitamins, and amount of concentrates. The Morrison feeding standards (Appendix Table III) show the amounts of dry matter, digestible protein, total digestible nutrients (or net energy), calcium, phosphorus, and carotene that should be provided per head daily for pregnant gilts, for pregnant older sows, and for brood sows nursing litters.

In Appendix Table VII will be found examples of well-balanced efficient rations for pregnant sows and for those which are nursing litters. Modifications can readily be made in these rations to adapt them to local conditions.

Corn or other grain ordinarily forms most of the ration for sows during pregnancy and also during the suckling period. In addition, sows should be fed supplements to provide plenty of protein, calcium, phosphorus, and vitamins.

As shown later, whether or not a protein supplement will be needed in addition to legume hay and grain for wintering pregnant sows will depend on the age of the sows, on the quality of the hay, and on the proportions of hay they actually consume. (1460) Sows that are suckling pigs should always be fed a protein supplement in addition to grain and either pasture or legume hay, as they need a considerably larger proportion of protein. A supplement should be used that provides protein of proper quality to correct the deficiencies in the proteins of the cereal grains.

The mineral and vitamin requirements of swine have been discussed in detail in the preceding chapter. When



ABILITY TO RAISE GOOD-SIZED LITTERS ESSENTIAL

For economical pork production, the sows must have the ability to raise good-sized litters of thrifty pigs.

sows are not on pasture, an abundance of vitamins is best assured by including at least 10 to 15 per cent of good-quality, field-cured legume hay in the ration. The vitamin needs are amply met by good pasture. If sows kept in dry lot cannot have plenty of legume hay of satisfactory quality, a B-complex vitamin supplement may be needed. (**1416**)

1457. Grains and grain substitutes for brood sows.—Because of its cheapness, corn is the chief grain fed to sows throughout the corn belt. Owing to the poor results when corn is unwisely fed to brood sows without proper supplements, the statement is sometimes made that corn should not form over one-third to one-half the ration for brood sows, as it is "too fattening." However, experiments have shown clearly that excellent results are secured when corn is the only grain, if it is properly supplemented and provided the allowance is strictly limited to the amount needed to keep the sows in thrifty condition without becoming too fat.

For example, in 3 Wisconsin trials a simple ration of ear corn, alfalfa hay fed in a rack, and 0.3 lb. tankage was slightly superior for wintering pregnant gilts to a more complex ration having only 35 per cent corn.[5] This mixture was 35 lbs. ground corn, 30 lbs. ground oats, 30 lbs. wheat middlings, and 5 lbs. tankage. The cost of feed per sow was 30 per cent less on the simple ration.

The other grains are satisfactory substitutes for corn in feeding brood sows. The relative values of the various grains for swine are stated in Chapters XX and XXI. Ground wheat is fully equal to corn in value, while ground barley or grain sorghum is worth slightly less per pound. Ground oats are excellent as part of the grain for brood sows. However, if oats form more than one-third to one-half of the grain allowance, a little more feed will be needed to keep the sows in proper condition than when corn is the chief grain.

1458. Grain alone or grain and minerals unsatisfactory.—Even when sows have been on good pasture during summer, a winter ration of grain alone or grain and minerals is very unsatisfactory. This is true even if the grain is yellow corn, which supplies considerable carotene. In the case of gilts, such a ration is apt to produce disastrous results, for their pigs are often weak and unthrifty and some may be dead at birth. Also, when sows are fed inadequately during pregnancy, there is sometimes a tendency for them to kill and eat their young pigs.

The poor results from feeding a ration of only corn and minerals to pregnant sows are shown by Indiana experiments.[6] Gilts wintered on only yellow corn and bone meal farrowed pigs that were dead or were so weak that they died within a day. The results were somewhat better on a combination of yellow corn, oats, and bone meal, but 36 per cent of the pigs were dead at birth or died within 3 days. On the other hand, when 5 per cent of meat scrap was added to the ration, the sows farrowed twice as many pigs, with only 13 per cent that were born dead or died within 3 days. This ration would have been still further improved by the addition of legume hay.

The results have likewise often been disastrous in experiments where other grains, such as barley, grain sorghum, or a combination of corn and oats, have been fed alone or with only mineral supplements to pregnant sows.[7]

Sows that have been on first-rate pasture throughout the growing season usually have good stores of vitamins and minerals in their bodies when winter starts. Sometimes mature sows may therefore produce fairly satisfactory litters when wintered until farrowing time on only yellow corn or corn and oats, if they are in a pasture lot where they can get a little green feed even in winter and where they are protected against a lack of vitamin D by exposure to sunlight.[8] However, such a method of feeding is unsafe for pregnant gilts and cannot be recommended even for mature sows.

1459. Importance of legume hay in winter rations.—The previous chapter has stressed the great importance of including good-quality legume hay as in-

surance against vitamin deficiencies in rations for brood sows not on pasture. (1383–1384) Legume hay excels in so many respects and also is such a cheap feed that a special effort should be made to provide it for sows in winter. Good-quality field-cured legume hay not only usually prevents any lack of vitamins, but it is also important as a source of protein and of calcium.

For insurance against vitamin deficiencies, a safe rule is to see that legume hay forms at least 10 per cent, and preferably 15 per cent, of the ration for sows in winter. Pregnant sows may well be fed all the legume hay they will eat in addition to a limited allowance of grain.

When choice, leafy alfalfa hay is used, sows will usually eat a sufficient amount if it is fed uncut in a simple slatted rack, preferably with a cover to keep out snow and rain. As stated later, this rack and also the feed troughs should be put at some distance from the hog barn or colony house, so the sows will secure plenty of exercise.

Red clover hay is usually less palatable to sows than alfalfa, and consequently they will often eat relatively little of it when fed uncut in a rack, even if the allowance of concentrates is restricted. Whenever the sows fail to eat enough legume hay, it should, if possible, be chopped or ground and mixed with the concentrates. The hay may be chopped at small expense by running it through a silage or hay cutter, preferably equipped with an alfalfa screen. If no cutter is available, the leaves and chaff which accumulate where the hay is pitched from the mow may be gathered up and mixed with the concentrates. To get the sows to clean up such chaff it may be necessary to feed the mixture as a slop.

Information is given in Chapter XVI concerning the composition and value of the various kinds of legume hay. Alfalfa excels clover, because it is richer in vitamins, protein, and calcium, as well as being liked better by swine. Soybean hay, lespedeza hay, cowpea hay, and other kinds of legume hay are satisfactory substitutes for alfalfa.

Mature sows are sometimes wintered on alfalfa hay without any grain or other concentrates, but this is inadvisable, for they will then not make the desired gains in weight during pregnancy. Also, although the cost for feed up to farrowing time will be low, Pennsylvania experiments show that it will later be necessary to feed them with great liberality on concentrates to provide even a fair milk flow for their pigs.[9] This will offset the saving in concentrates before farrowing.

1460. Legume hay as the only protein supplement.—For wintering pregnant sows a year old or more, a ration consisting of only grain, legume hay, and a mineral supplement is satisfactory, if the hay is of excellent quality. When leafy, palatable alfalfa hay is fed to such sows, they will generally eat a pound or more per head daily, if the allowance of grain is strictly limited. Under such conditions there may be little or no advantage in adding tankage or similar protein supplements to the ration throughout the winter.[10] When the sows do not eat so much hay or if it is of only fair quality, then a protein supplement should be added. This is especially important during the last 2 or 3 weeks before farrowing, when the growth of the unborn pigs is most rapid.

In the case of pregnant gilts, a small amount of such a protein supplement as tankage, fish meal, soybean oil meal, or skimmilk had best be added to a ration of grain and legume hay, unless the hay is of choice quality and unless the gilts are forced to eat enough hay by mixing ground or chopped hay with the grain.

In Michigan experiments the results were satisfactory when both mature sows and gilts were wintered on a mixture of 2 parts ground corn or corn and oats and 1 part of ground choice-quality, second-cutting alfalfa hay.[11] Some of the hay was also fed unground in a rack and a mineral mixture was supplied to furnish additional calcium and phosphorus. The results were about as good on this home-grown ration as when 5 per cent of tankage was included in the mixture in place of the alfalfa hay.

In other Michigan trials the results were as satisfactory when sows a year old or older at breeding time were wintered on a limited amount of corn plus good alfalfa hay fed in a rack, as when they were fed a mixture of ground corn and ground hay.[12] With gilts, there was some advantage in forcing them to eat a goodly proportion of alfalfa hay by feeding a mixture of 2 parts of ground corn and 1 part of ground hay.

In 4 Wisconsin trials in which pregnant gilts were wintered on a limited amount of ear corn, with alfalfa hay fed in a rack, there was an appreciable advantage from feeding 0.3 lb. of tankage per head daily in addition.[13] The gilts fed tankage not only made somewhat larger gains, but also the average weight of the pigs at birth and the proportion of vigorous pigs were slightly greater. When credit was allowed for the greater gains, the feed cost per head daily was a trifle less for the gilts fed tankage.

When barley, oats, wheat, or grain sorghum is fed instead of corn, there will be somewhat less advantage in adding a supplement such as tankage to a ration of grain and legume hay. This is because these grains are considerably higher in protein.

Legume hay is not very satisfactory as the only protein supplement to grain for brood sows while they are nursing their litters. This is because such a ration does not supply enough protein or protein of sufficiently good quality for high milk production by sows.

1461. Protein supplements for brood sows.—Protein supplements of animal origin, such as tankage, meat scrap, dairy by-products, and fish meal, are of especially high value for brood sows, just as they are for growing and fattening pigs. Ideal winter rations for pregnant sows are combinations of grain and legume hay, along with small amounts of these efficient protein supplements.

Tankage was just as satisfactory as a mixture of protein supplements for sows during pregnancy and the suckling period in Indiana trials.[14] Only 5 per cent of tankage supplemented corn effectively.

If skimmilk or buttermilk is available for the sows, there is no better ration than grain and legume hay, plus 4 to 6 lbs. of either of these dairy by-products per head daily. There is no need whatsoever of adding purchased concentrates to such a ration, unless perhaps a little wheat bran or linseed meal shortly before farrowing, to keep the sows in a laxative condition.

Whey is relatively low in protein, but the protein it does contain is of such high quality that a ration of whey, grain, and legume hay is satisfactory for sows. If legume hay is not fed, a small amount of a feed like linseed meal, wheat middlings, or wheat bran should be added to a ration of grain and whey, especially if the grain is corn.

Soybean oil meal is an excellent protein supplement for brood sows. However, it has been shown previously that when sows are kept in dry lot for a long time, nutritional deficiencies are more apt to develop on a ration of corn, soybean oil meal, and minerals, than when an animal by-product feed is included. (1384) As has been stated, such trouble can usually be prevented by including at least 15 per cent of good alfalfa or other legume hay in the ration. Peanut oil meal, peanuts, or cooked soybeans can be used in the same manner as soybean oil meal.

Such supplements as wheat middlings, wheat bran, and linseed meal are fairly satisfactory when the sows eat a considerable amount of good legume hay.[15] However, it is best to feed in addition a small allowance of one of the more efficient protein supplements. If sows have been on excellent pasture during summer, they may produce normal litters when fed only grain and such a supplement as wheat middlings or linseed meal during pregnancy. However, feeding such a ration is unsafe, for the results may be poor, even under these conditions. Feeding this kind of a ration to sows kept continuously in dry lot produces disastrous results.[16]

1462. Animal by-products as the only supplements.—Except from the standpoint of vitamins, such animal by-products as tankage, fish meal, or skim-

milk are ideal protein supplements for brood sows. Therefore, if the sows have been on good pasture during the summer and fall and if they are out in the sunshine during the winter, they will usually produce satisfactory litters when fed only grain and such supplements during the winter.

However, it is much safer and also usually cheaper to feed sows some well-cured legume hay in addition. This will insure their receiving sufficient vitamins and will help prevent constipation. As a result, the pigs will often be stronger and more thrifty than when no legume hay is supplied. Also, the addition of legume hay to the ration will generally reduce the feed bill for wintering the sows.

1463. Roots or tubers; silage.—The experiments reviewed in Chapter XIX show that roots are not a satisfactory substitute for legume hay in feeding brood sows. (**634**) This is because they are low in protein, calcium, and phosphorus; they supply little or no vitamin D; and with the exception of carrots, sweet potatoes, and yellow rutabagas, they are deficient in carotene. When it is economical to do so, roots or tubers can be substituted for part of the grain in feeding brood sows.

Corn silage is not usually considered a satisfactory feed for brood sows, for they leave most of the forage and eat the grain. However, in recent Indiana trials brood sows produced satisfactory litters when wintered on well-eared corn silage with protein, mineral, and vitamin supplements.[17]

Alfalfa or other legume silage can be used instead of legume hay as a vitamin supplement for swine. But legume silage does not usually have enough vitamin D to be an effective vitamin D supplement. It is therefore generally better to include good-quality, field-cured legume hay in winter rations for swine.

1464. Minerals.—Brood sows should always be provided regularly with salt. (**1398**) The best plan is to let them have access to it in a suitable box, where they can take what they wish. In an Iowa test various lots of yearling gilts, wintered on rations which included some tankage, ate from one-twentieth ounce to one-fourth ounce per head daily.[18]

Whether or not it will be beneficial to supply any mineral supplement other than salt for brood sows will depend entirely on the ration that is fed, as has been emphasized previously. (**1397**) In sections where there is trouble from goiter, or hairlessness, in new-born pigs, iodine should always be supplied the sows during at least the last 12 weeks of pregnancy. (**1402**)

When sows are fed such animal by-products as skimmilk, tankage, meat scrap, or fish meal and in addition are on pasture or are supplied with plenty of well-cured legume hay, there is generally no need to add other mineral supplements to provide calcium and phosphorus. This is shown by Wisconsin experiments in which young gilts were raised from shortly after weaning on an ordinary well-balanced concentrate mixture of corn, oats, wheat middlings, linseed meal, tankage, and salt, and continued on the same mixture during pregnancy.[19] In summer the gilts were on good pasture and in winter they were fed well-cured alfalfa hay in a rack. Other lots of gilts were similarly fed each year, except that either 2 lbs. of steamed bone meal or 2 lbs. of ground limestone were mixed with each 100 lbs. of the concentrates. There were no benefits whatsoever from adding these mineral supplements to the ration, because it already had plenty of calcium and phosphorus.

If a ration is used which is low either in calcium or phosphorus, it is very important to add a supplement that will correct this lack. Unless this is done, the sows may themselves suffer from the deficiency, and also they are apt to produce unsatisfactory litters.[20] When sows have been on first-rate pasture in summer, they may sometimes have satisfactory litters even if fed a ration low in calcium or phosphorus.[21] However, this is risky, as the results are apt to be poor.

1465. Amount of concentrates for pregnant sows.—It is just as important not to overfeed pregnant sows as it is to feed them a well-balanced ration. If they become too fat, they are apt to have weak pigs, and they may be so restless and clumsy at farrowing time that many of the pigs are killed. When sows are too fat at breeding time, they may even fail to conceive. On the other hand, a sow which is too thin lacks the reserve nutrients necessary to nourish her pigs properly before and after birth.

A mature sow which is in vigorous, active condition at the beginning of the breeding season in the fall should be fed so as to gain 75 to 85 lbs. by farrowing time in the spring. This will about cover the loss in weight which will occur at farrowing and while she is nursing her pigs. More of this gain should be made during the last 4 to 6 weeks of the gestation period than during the first part, for most of the growth of the unborn litter occurs then.

Gilts should gain 100 to 125 lbs. from breeding time to farrowing, or a little less than 1 lb. per head daily.

If mature sows are fed plenty of legume hay, about 1.00 to 1.25 lbs. of concentrates daily, per 100 lbs. of live weight, will be sufficient during the first 10 to 12 weeks, and from 1.25 to 1.50 lbs. during the last 4 to 6 weeks of the gestation period. Sows will eat much more feed than this if it is supplied, and they will usually squeal lustily for a more liberal allowance.

One must therefore not pay any attention to their desires, but feed only enough to keep them at the proper weights and in the desired condition. It pleases an experienced hog raiser to see his sows industriously hunting for the last grains of corn, for he knows that they are securing the exercise which is so essential for a good pig crop. Furthermore, he knows that his feed bill will be much less than if he had allowed mistaken generosity to rule in feeding the sows.

Yearlings and especially gilts should receive more concentrates in proportion to their live weight, in order to provide for their growth. An average allowance of 1.3 to 1.6 lbs. concentrates daily per 100 lbs. live weight in addition to legume hay will usually be plenty for yearlings, and 1.5 to 2.0 lbs. daily per 100 lbs. live weight for gilts.

In a recent Illinois trial the farrowing results were better when either gilts or older sows were fed about 4.5 lbs. per head daily of a concentrated ration during gestation, than when they were either fed more or fed only 3.0 lbs. a day.[22] Wisconsin studies indicate that sows fed a somewhat limited ration after breeding may farrow slightly more pigs per litter than those which are fed too liberally.[23]

When a number of sows are kept on the farm, it pays to sort them into two or more lots, depending on age, condition, and disposition. The amount of feed for each lot can then be regulated so that all the sows are kept in the proper condition.

1466. Methods of feeding brood sows.—Pregnant brood sows are ordinarily hand-fed the amount of concentrates they need. Occasionally, they are fed by means of a self-feeder. Chopped or ground legume hay or some other bulky feed, such as oat mill feed, then must be mixed with the grain or other concentrates, so that the sows will not eat too much concentrates and get too fat.

A mixture for self-feeding to pregnant gilts should contain 25 to 40 per cent of hay or other bulky feed, and for older sows the percentage should be greater. Thus, in Nebraska trials mature pregnant sows were wintered successfully by self-feeding a mixture of 3 parts by weight of chopped alfalfa hay and 1 part of ground corn.[24] It is often necessary to change the proportion of hay at intervals during the winter, so the sows will keep in the desired condition.

In some experiments the results have been satisfactory when pregnant sows have been self-fed suitable mixtures, but in other tests hand feeding has been decidedly preferable.[25] Generally, the amount of feed consumed has been appreciably greater when sows have been

self-fed, and often the litters have been a little less satisfactory.

In Texas experiments in which various methods of feeding brood sows were compared, excellent results were secured when sows were fed the entire daily allowance in the morning at one feeding, instead of feeding them twice a day, as is usual.[26]

If sows waste considerable of a fine concentrate mixture when fed dry in a trough, the wastage may be prevented by pouring water on the mixture in the trough. In very cold weather, pouring warm water on the concentrate mixture in this manner or feeding warm slop induces the sows to take more water than they would otherwise.

1467. Exercise; shelter.—It has already been stressed in this chapter that sows should be on good pasture during as much of the year as possible. When pasture is not available, they should be induced to take plenty of exercise. In the corn belt a common practice in the fall is to turn the brood sows into the corn fields after the corn has been gathered, to pick up any scattered ears. This not only provides an abundance of exercise but also utilizes feed that would otherwise be wasted.

During the winter it is a good plan to feed the sows at some distance from their sleeping quarters. If there is at this place a rack with choice legume hay, the sows will make many trips back and forth each day. When sows are fed ear corn and the allowance is properly limited, they will spend considerable time searching for the last kernels, and the longer they can be kept on their feet, the better it is for their health. If a ground concentrate mixture is fed, it is often a good plan to scatter a little shelled corn, whole oats, or sheaf oats on the ground for the sows to work over. Sows heavy in pig should not be compelled to plow through snowdrifts, but paths should be made for them. Ashes or sand should be sprinkled on icy places, else they may slip and wrench themselves, which may result in abortion.

The benefits from letting sows have access to an outside lot during winter are shown by Indiana and Kansas tests.[27] Sows fed poor rations produced better pigs when allowed exercise and access to dirt in outside lots than when confined inside. In an Indiana trial gilts allowed to roam in a pasture field during winter produced more vigorous pigs than did others kept in a small lot. The beneficial effects in these trials may have been largely due to the exposure to sunlight, to the sows getting minerals by eating dirt, and to their securing a little needed green feed, rather than to the exercise alone.

The shelter requirements for the various classes of swine have been discussed in Chapter XXXIV. (**1440**)

1468. Summer care of brood sows.—If good pasture is provided, the problem of feeding brood sows in summer after the spring litters are weaned is easily solved. Where sows raise but one litter of pigs a year, they need little or no concentrates in summer, if they are on such first-class pasture as alfalfa, clover or rape. Grain should be fed if needed to keep the sows in thrifty condition, and in any event they should get some grain for 2 or 3 weeks before breeding time in the fall.

On such protein-rich pasture, only a small amount of protein supplement is needed to balance the ration, even when corn is the grain fed. For example, dry sows on alfalfa, clover, or rape pasture will do well on corn with no more than 4 to 5 per cent by weight of tankage, or on equal weights of corn and either skimmilk or buttermilk. When barley, oats, or wheat is fed, little or no supplement is needed if the pasture is good.

Where sows raise two litters a year, they will need more concentrates in addition to pasture, because of the added drain on their bodies. They should be fed so as to make about the same gains as recommended for sows in winter.

1469. The breeding season.—Sows are in the best condition for breeding when they are not fat, but are gaining in weight. About two weeks before breeding starts, the sows should be "flushed," just as in the case of ewes. (**1302**) This means increasing their feed

so they will gain 0.50 to 0.75 lb. a day. It is believed that sows thus treated are more apt to have large litters, and also to come in heat more promptly and to become pregnant from the first breeding.

The ration at this time should be similar to that fed during the gestation period and should contain a protein supplement. If possible, the sows should always be on pasture at this season.

Sows usually remain in heat about 2 to 3 days, and if not bred will return in heat at intervals of about 21 days.

1470. The boar.—The feed and care of the boar do not differ materially from that of the sows. The boar should be kept in thrifty condition, neither too fat nor run down in flesh, as either extreme may injure his breeding powers. In summer he should be kept in a lot where there is good pasture, and in winter he should have the freedom of a paddock of sufficient size so that he will get abundant exercise. A good plan is to have a small colony house for shelter at one end of the lot, and to feed the boar at the other end.

Although the safest plan is to see that boars can get plenty of exercise in outside lots, in a recent Nebraska experiment boars kept for 3 successive generations in a barn with little room for exercise, were fertile and sired normal litters.[28] However, they were fed an excellent ration, including alfalfa hay, a B-complex vitamin supplement, and irradiated yeast to supply vitamin D. Also, they were never allowed to become too fat.

The most common mistake made in feeding boars is to overfeed them and get them so fat that their breeding powers are seriously injured. Except during the breeding season, when more feed is required, about 1 lb. of concentrates daily per 100 lbs. live weight is sufficient in summer for fairly mature boars on good pasture. A little more concentrates will be needed in winter. Young boars should receive sufficient feed to keep them growing thriftily.

Two weeks before the breeding season starts, the ration should be increased somewhat, so the boar will be gaining in weight when service begins. The amount to be fed during the breeding season will depend on how much the boar is used. In general, he should be fed enough to prevent his losing much weight. Many breeders prefer not to feed much corn to boars at this time, but to use instead concentrate mixtures made up of other grains and a considerable proportion of protein supplements, such as wheat middlings or bran, linseed meal, tankage, and chopped legume hay.

A boar should not be used for breeding until he is 8 months of age, and then he should preferably not breed more than one sow a day and 15 to 20 in a season.[29] Yearlings and older boars should be capable of breeding 25 to 45 sows, if the services are well distributed. In breeding gilts or small sows to a mature boar, a breeding crate can be used to advantage.

1471. Gestation period; breeding studies.—The average gestation period of sows is usually given as 112 to 115 days. The length of the gestation period is not affected by the age of the sow, her size, or feeding liberal or scanty rations.[30]

The boar probably does not have any appreciable influence on the number of pigs in the litter, unless he is approaching sterility. On the other hand, he does have an influence on the number of pigs his daughters produce.

A sow that produces a small number of pigs in her first and second litters will tend to have a small number in subsequent litters. The second litter is a somewhat better basis of selection than the first litter, in which the number of pigs is more variable.

The light pigs in a litter usually make less rapid and less economical gains than those that are of average size or heavier.[31] If there are runts in a large litter, it may be best to kill them rather than to waste feed and care upon them. The average weight of pigs at birth is about 2.5 lbs.

1472. Gilts vs. older sows.—It is well known that gilts usually farrow fewer pigs per litter than do older sows. However, they raise a somewhat larger

percentage of the pigs farrowed. In co-operative studies by the United States Department of Agriculture and corn-belt experiment stations, it was found that gilts one year old at farrowing time had an average of 7.92 pigs per litter and raised an average of 5.07 pigs to weaning time.[32] Gilts 1½ years old had 8.49 pigs per litter and raised 5.53. Sows 2 years old farrowed 9.49 pigs per litter and raised 5.99, which was the largest average number raised for any age. However, the average number of pigs farrowed increased up to 3½ years of age, when the average was 9.93 pigs.

The pigs from gilts average slightly smaller in birth weight than those from older sows and also tend to make slightly less rapid gains. In Minnesota studies pigs from gilts averaged about 4 lbs. lighter at weaning time than pigs from older sows, and in Wisconsin studies the difference was 9.4 lbs. at 98 days of age.[33]

Practical hogmen differ widely in their opinions concerning the relative economy of proven older sows and of gilts for pork production. All admit that older sows raise somewhat larger litters of pigs and that their pigs tend to make slightly more rapid gains. However, gilts have certain advantages, as well. Their chief superiority is that they are continuing to grow and appreciate in value for pork while they are producing their pigs. Also, because of their greater smoothness and lighter weight after raising one litter of pigs, they usually sell at a higher price on the market than do older sows.

It was found in Minnesota cost accounting studies that somewhat the best net returns were secured where only about one-half of the sows that farrowed were gilts.[34] Under this system, the sows which produce and raise the best litters are retained as long as they are useful.

In a similar Illinois study it was concluded that there was little choice between gilts and proven older sows, except when the price of pork was sufficiently favorable so that the gain in weight of the gilts could be sold at a decided profit.[35] It should be borne in mind, however, that even young fat sows, after raising their first litters, commonly sell at a considerable discount from the price of fat pigs. Differing from these studies, it was concluded from experiments by the United States Department of Agriculture in Montana and South Dakota that gilts produced pork more economically than did older sows.[36]

The Illinois and Minnesota studies show clearly that when spring-farrowing sows are retained in the breeding herd for further litters, it is unprofitable to raise only one litter a year from them. As many of them as possible should be bred for fall litters in the two-litter method of pork production described later. (**1489**)

The breeder of purebred swine should certainly not rely chiefly on gilts for his breeding herd. Sows which produce especially good litters and which are good milkers and careful mothers should be retained as long as they are useful. Only the offspring from such proven mothers should be chosen for replacements. By careful selection much can be done to build up a herd which is decidedly more profitable than the average. Unless there is some very good reason to expect better returns in the future, one should discard a sow raising a litter of less than 5 pigs, or one which is vicious with her pigs, in spite of being properly fed and cared for. A sow that can save and raise 8 good pigs is an excellent producer and should be retained.

1473. Preparations for farrowing.—Lack of care at farrowing time results in many young pigs being lost through disease or parasites, or from being lain on by the sows. In some seasons 40 per cent of the pigs farrowed in the corn belt die from these causes. These losses can largely be prevented by the right care and management.

At least 3 days before farrowing, each sow should be removed from the herd and placed in a separate farrowing pen, to become accustomed to her surroundings. Previously, the sow should have been cleaned as described later, and the pen should have been cleaned and scrubbed to prevent infecting the young

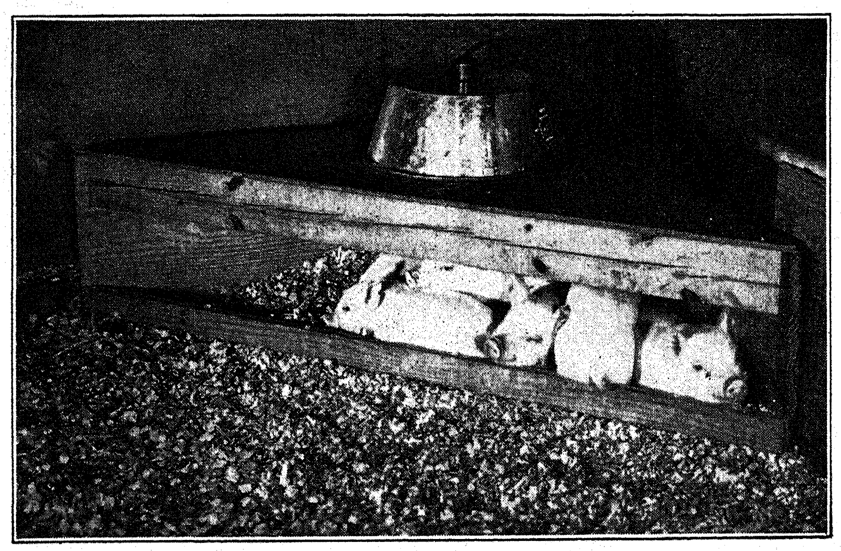
pigs with round worms and other parasites. (1491)

If the breeding dates have not been recorded, the sows should be watched closely as the farrowing season approaches, and each sow should be put in the farrowing quarters as soon as the udder and teats begin to fill. After a sow starts to arrange her nest, she may be expected to farrow within 12 hours. Recording the breeding date is highly important where the litters come before the weather is warm, for otherwise sows will often farrow before it is expected, and their litters may perish from cold or lack of proper care.

A farrowing pen should be dry, well ventilated, free from drafts and well lighted. If possible, it should be exposed for a part of each day to direct sunlight, so it will be warmer.

When a sow farrows during the pasture season, it may be most convenient to have her farrow in a colony house located in a pasture that is free from round worms and other parasites. However, it may then be more difficult to aid her in case she has trouble in farrowing.

Unless electric pig brooders or farrowing crates or stalls are used, each farrowing pen should have guard rails, or fenders, to help prevent the sow from squeezing the pigs against the wall or crushing them when she lies down. These can be made by fastening planks edgewise, like a shelf, 8 to 10 inches above the floor, along both sides of the corner in which the sow makes her bed. If the farrowing pen has a concrete floor, a wood overlay in the nest corner makes the sow's bed warmer and drier.



An Electric Pig Brooder

An electric pig brooder in a corner of the farrowing pen protects the young pigs and keeps them warm in cold weather.

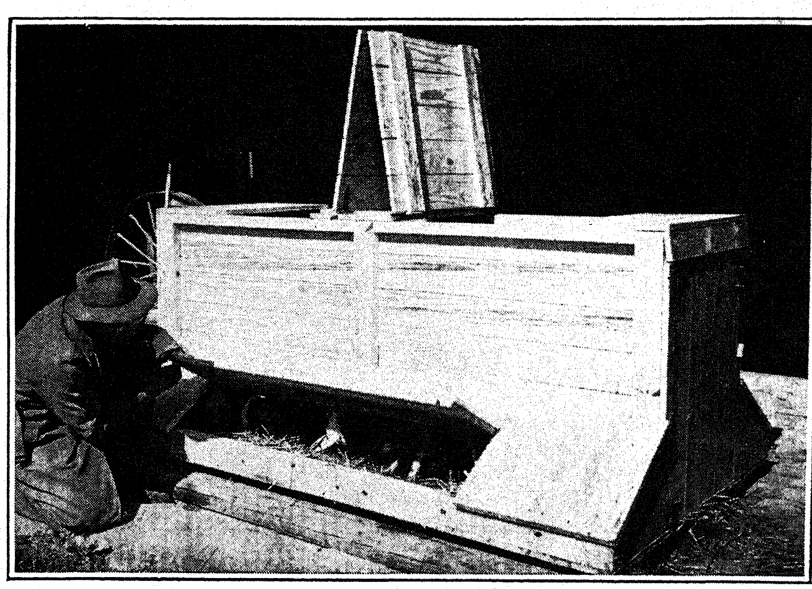
The farrowing place should be sufficiently warm so that a deep nest is not necessary to prevent the new-born pigs being chilled, for they may be crushed in a deep, bird-like nest. Cut straw or hay, shredded stover, chaff, or leaves are best for bedding. Long straw or hay may entangle the pigs.

In cold weather many baby pigs die from chilling, because the mechanism for regulating the body temperature is not well developed until the pigs are at least 2 to 3 days of age.[37] These losses can be largely prevented by some means of keeping the pigs warm during this critical period.

A pig brooder in a corner of the

pen, warmed with an electric light or heat lamp, protects the young pigs and keeps them warm in cold weather. Because of the warmth, the pigs spend much of the time there, where they cannot be lain on or crushed. Where electricity is not available, a similar but unheated hover can be used.

Another method of reducing losses of new-born pigs is the use of farrowing crates or stalls. In these, the sow is so closely confined that she cannot turn



A Portable Farrowing Crate

In a farrowing crate the sow is so closely confined that she cannot turn around. The pigs have access to the spaces on the sides, which serve as brooders.

around. The pigs have access to spaces on the sides, which serve as a brooder and may be heated. Still another way of keeping young pigs warm in cold weather is by suspending a heat lamp over the sow's nest.

Some hogmen use sloping floors in the farrowing pens to prevent the sows from crushing or injuring the pigs. The sow will generally lie with her head up the slope, and away from the side of the pen, where the pigs can be safe.

As soon as the sow is put in the farrowing quarters, her ration should be reduced, for she gets little exercise. The ration should also be made more laxative. A good rule is to feed only one-half to two-thirds as much concentrates as previously, with wheat bran forming one-third of the ration, by weight. Linseed meal is also a helpful addition at this time, and legume hay should be included in the ration, if possible.

1474. Farrowing time.—Few sows need help at farrowing time, but the herdsman should be on hand to render assistance, if necessary. Otherwise, he should not disturb the sow. In large herds it pays to have an experienced man near during the night at this time to inspect the sows every three hours. The farmer with only a few sows will find that a few night trips to the hog house at farrowing time will save many a litter, and prove a wise investment of his time and energy.

In cold weather it is a good plan to dry new-born pigs with a cloth as they arrive. If the pen is not equipped with an electric pig brooder, it is well to put the pigs in a basket or box lined with sacks or other cloth. A jug of hot water

Warm bricks wrapped in cloth can be placed in the center to keep the pigs warm, and the receptacle lightly covered to hold the heat. Separating the pigs thus from the sow as they are farrowed is also wise in the case of heavy, clumsy sows, or those which are very restless. Sows properly handled before farrowing will not usually resent such separation.

The pigs should be kept in this box or basket until farrowing is over, provided the time is not more than 2 or 3 hours. When they are returned to the sow, each pig should be placed at a nipple, and the litter should be watched until their safety is assured. In the case of a very cross sow it may be advisable to keep the pigs away from her for a day or so, returning them to nurse every 2 to 4 hours.

To prevent losses due to navel infection, the navel of each pig should be dipped in tincture of iodine as soon as possible after birth. Experienced hogmen commonly break off the sharp needle teeth of the young pigs with nippers made for this purpose, so the pigs will not lacerate the udder of the sow or wound each other as they tussle among themselves.

Identifying the young pigs by ear-notching them is highly advisable, even in grade herds, so that gilts can be selected for the breeding herd from the best dams.

If brood sows have been kept thrifty by feeding them well-balanced rations and by inducing them to take plenty of exercise, and if constipation is prevented, little trouble will be experienced from sows failing to furnish enough milk for their pigs or from being restless and irritable, which may lead to their eating the young. If a sow has a feverish udder, which is often a result of constipation, a light application of kerosene and lard, well rubbed in, will reduce the congestion and relieve the pain.

Breaking Off the "Wolf" Teeth

Usually experienced breeders break off the "wolf" teeth, or temporary tusks, which pigs have at birth, to prevent lacerating the udder of the sow or wounding the other pigs. (From Wisconsin Station.)

1475. After farrowing.—A sow should have no feed for 12 to 24 hours after farrowing, but should have plenty of water that is not too cold. If she frets

for feed, a handful of wheat bran may be put on top of the water to quiet her.

For the first feeding the sow should get only a double handful of a mixture that is laxative, preferably containing considerable wheat bran. The amount of concentrates should be increased very gradually or the milk flow may be stimulated too soon. This may result in the sow having milk fever or suffering from a caked udder, or in the pigs getting scours. For the second day 2 or 3 lbs. of feed, divided into 2 meals, are sufficient.

During the first few days it is best to use a bulky concentrate mixture containing at least one-third ground oats or wheat bran. Such a mixture may then be changed gradually to the one that is to be fed during the suckling period. After 7 to 10 days a sow should be getting all the feed she will clean up. By this time, the sows and litters should, whenever possible, be put on clean pasture, free from infestation with round worms or other parasites. (1491)

Occasionally, pigs less than a week of age are affected by the "baby-pig disease," or hypoglycemia, in which they become dull and listless and show little desire to nurse. In this condition there is a serious deficiency of glucose in the blood, perhaps caused by semi-starvation, owing to poor milk yield by the sow or to digestive disturbances in the pigs.[38] Pigs not too severely affected may recover if hand-fed every 2 or 3 hours 1 to 2 teaspoonful doses of corn syrup diluted with twice as much warm water.

1476. Milk production of sows.—The gains made by suckling pigs depend largely on the amount of milk their dam produces. It is therefore important to select herd replacements from good milk-producing ancestors.

In various experiments the daily milk production of sows has varied widely, ranging from 4.9 to 11.7 lbs.[39] The daily amount usually reaches the peak from the third to fifth week of lactation. During an 8-week suckling period a good sow should yield 300 to 400 lbs., or even more.

To produce this much milk in this brief period, requires a liberal supply of nutrients. This is shown by the fact that the milk she yields contains several times as much protein, calcium, and phosphorus as there is in the new-born pigs and in the fetal membranes.[40]

Several studies have been made on the composition of sow's milk.[41] It is more concentrated than cow's milk, containing much more protein and fat. (Appendix Table I.) It generally does not differ greatly from cow's milk in vitamin content. As in the case of the milk of other species, the vitamin A content is affected greatly by the vitamin A or carotene content of the ration.

If the feed of sows is very high in percentage of fat, such as fat-rich garbage, the fat percentage of the milk may be increased considerably.[42]

In North Dakota tests it was found that the average interval between the nursings by pigs was 62 minutes, and the longest interval recorded was 175 minutes.[43] There was no marked difference between the intervals in the daytime and at night.

1477. Evening-up litters; orphan pigs.—If a sow has too many pigs to nurse adequately, some should be transferred, if possible, to a small litter of the same age. The method is not successful unless the foster mother has extra teats that are giving a good flow of milk when the transfer is made. The same method can be used in the case of orphan pigs.

The sow should be taken out of the pen when the pigs are added to her litter, and the pigs should be allowed to run together for 10 to 20 minutes before the sow is returned to the pen. Sprinkling a weak solution of stock dip over all the pigs will make it difficult for the sow to distinguish the new arrivals by smell.

Where no sows with litters of about the same age are available for raising orphan pigs, they may usually be raised successfully by hand, if the herdsman has enough patience. It is best to feed the pigs whole sweet cow's milk 5 to 6 times daily until they are 2 to 3 weeks old, when the number of feedings may be reduced to 3 a day. However, in Iowa tests satisfactory results were secured

when pigs were fed only 3 times daily from the beginning.[44]

Some use a nursing bottle at the start, but with patience even the youngest pigs can be taught to drink milk from a shallow dish. The pig's mouth and nose are pushed into the milk, care being taken not to continue the process so long that the pig is strangled. The milk should be about body temperature for the first week or two. To supply the traces of iron and copper necessary to prevent anemia, a few drops of a saturated solution of copperas (ferrous sulfate) should be added to each quart of milk.[40] (**1403**)

A maximum of one quart of milk a day is enough per pig, if they are supplied with a suitable concentrate mixture as soon as they can be taught to eat solid food. Care should be taken to supply fresh water at all times. If whole milk is not available, fresh skimmilk or even buttermilk can be substituted, according to the Iowa tests. It is not necessary to add cream or sugar to whole milk for orphan pigs, though this is sometimes recommended.

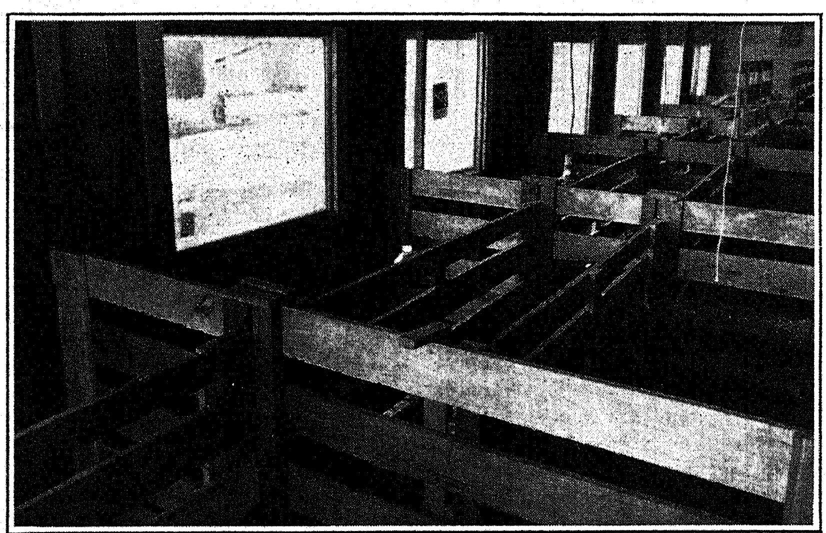
If young pigs do not get the colostrum milk from a sow, it is much more difficult to rear them, as the colostrum protects them against various infections. (**270**) When the orphan cannot get colostrum from a sow, it should be fed colostrum from a cow for a couple of days, if possible.

A commercial milk replacer can also be used for raising orphan pigs, instead of cow's milk. (**1483**)

III. Raising the Pigs

1478. Feeding sows that are suckling litters.—During the suckling period, brood sows must be fed much more liberally than during pregnancy, because of the additional nutrients needed for the production of a good flow of milk. Not only should they receive more grain to furnish the necessary total digestible nutrients and energy, but also the supply of protein, calcium, phosphorus, and vitamins must be considerably greater, since milk is rich in these nutrients.

In general, the nutrient requirements of brood sows suckling litters are similar to those of dairy cows for milk production. The requirements of brood sows of various weights are stated in the feeding standards in Appendix Table III.



A Hogbarn with Removable Farrowing Stalls

At farrowing time, the sow is confined to a farrowing stall, just as in a farrowing crate.

It is essential that sows with litters be fed enough concentrates to produce a good milk flow. Otherwise, the young pigs will not get a good start. It should be remembered that at no other time do pigs make as economical gains as when suckling their dams. When on full feed, a 400-lb. sow nursing a litter will need 8 to 12 lbs. of concentrates a day, the exact amount depending on her condition and on the number of pigs in the litter.

The concentrates may consist chiefly of corn and other grains, but sufficient protein of good quality must be fed to balance the ration properly. (1385) Such supplements as tankage, meat scrap, fish meal, dairy by-products, or soybean oil meal are especially important when the sows are not on pasture. Protein supplements that supply poorer-quality protein, such as linseed meal, cottonseed meal, or wheat middlings, may be used in combination with those first mentioned.

As stated in the preceding chapter, rations for gilts nursing litters should have not less than 15 per cent of total protein, and rations for mature sows at least 14 per cent. (1388) Experiments have proved that even when sows have been fed good rations during pregnancy, rations deficient in protein when they are nursing their litters produce poor results.[45] The gains of the pigs are much less, there is a greater death loss, and the sows lose more weight.

When the sows and pigs cannot be put on pasture by the time the pigs are 2 weeks old but are confined to pens and paved lots, anemia of the suckling pigs should be prevented by using one of the methods described previously. (1403) For sows and pigs not on pasture, it is also wise to supply a suitable mineral mixture in addition to common salt, unless one is sure there is no lack of calcium or phosphorus in the ration.

If the sows are not on pasture, 5 to 10 per cent of ground or chopped alfalfa or other legume hay should be included in the concentrate mixture to furnish carotene, vitamin D, and other vitamins, or choice legume hay should be fed in a rack.

Corn may be fed as ear corn or shelled corn (preferably soaked if it is hard and dry), or it may be ground and mixed with the other concentrates. The smaller cereals should always be ground for sows, if possible.

Because of the large amounts of nutrients needed in milk production, sows that are good milk producers may lose much weight while nursing their litters, even when they are fed liberally. This means that the amount of nutrients they can assimilate from their feed is insufficient to furnish the nutrients in the milk, and therefore they draw temporarily on the store in their bodies.

Several example rations for brood sows suckling litters are given in Appendix Table VII. These will serve as guides in making up a ration that will be most economical under one's local conditions.

1479. Methods of feeding brood sows and litters.—Brood sows with litters may be hand-fed 2 or 3 times a day, or they may be self-fed. In the self-feeding method both sows and pigs have access to a suitable concentrate mixture at all times in a self-feeder.

If a sufficient amount of a bulky feed, such as alfalfa meal, wheat bran, or oats, is included in the self-fed mixture, the sows may be put on the self-feeder when the pigs are only 2 to 3 days old.[40] The mixture should gradually be made more concentrated as the sows and pigs need more nutrients.

Self-feeding not only saves labor, but it also ensures a plentiful supply of feed at all times. It is especially desirable when several sows are in the same lot, as there is no quarreling at the feed trough, and each pig can get all it wants. To save feed, sows with less than 5 or 6 pigs had best be sorted out and fed a limited ration.

Self-feeding sows and litters proved preferable to hand-feeding in experiments by the United States Department of Agriculture and also in a Kansas test.[46] In the former trials, self-fed sows gained an average of 12.8 lbs. and their pigs an average of 20.4 lbs. during 41 days, while hand-fed sows lost an average of

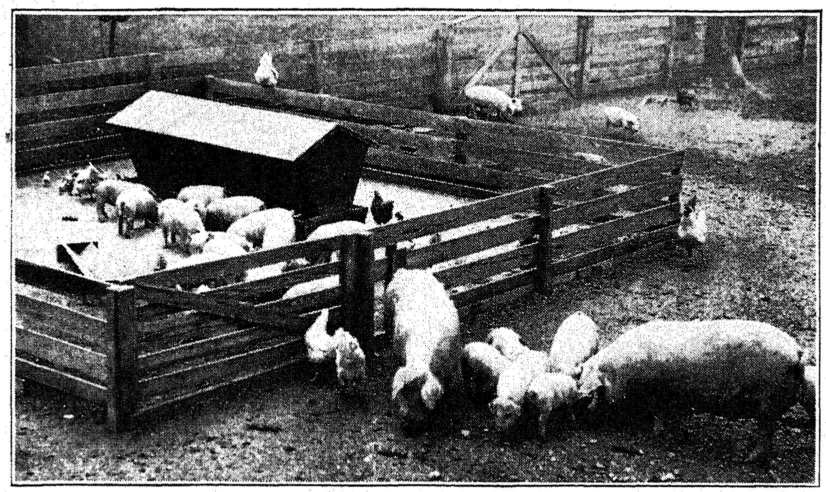
11.6 lbs. and their pigs gained an average of 17.0 lbs. during 44 days. The self-fed pigs also continued to make more rapid gains after weaning. For 100 lbs. gain of sows and litters combined, only 441 lbs. of feed were required by the self-fed lot, in comparison with 603 lbs. for the hand-fed lot. Also, when the sows were bred before their pigs were weaned, 81 per cent of the self-fed sows settled at the first service and only 47 per cent of those that were hand-fed. It has been shown previously that the self-feeding method is not adapted to feeding pregnant sows, unless the proper amount of very bulky feed is included in the mixture, and the proportion of such feed is changed from time to time so as to keep the sows in proper condition. (1466)

When sows suckling litters are self-fed a well-balanced ration, there is little advantage in supplying separate feed for the pigs in a creep.

Good pasture, free from infestation with parasites, is especially beneficial to young pigs, because of the protein, minerals, and vitamins it provides, and also because pigs get an abundance of exercise when on pasture.

If the pigs show a tendency to become too fat the first few weeks, the dam's ration should be reduced gradually, so she will give a little less milk. Scours should be avoided by keeping the quarters dry and clean and the troughs sanitary. Overfeeding the sows or letting the pigs run out in a cold rain are other frequent causes of this trouble.

Boar pigs not to be kept for the breeding herd should be castrated when 3 to 6 weeks old. This should be done on a clear, cool day, and the pigs should be kept in dry, clean quarters afterwards. Before the operation the pigs should receive only a light feed.



YOUNG PIGS FEEDING IN A CREEP

When the sows are hand-fed instead of being self-fed, additional feed should be supplied the suckling pigs by means of a creep.

1480. Creep-feeding; pig starters.—When sows suckling litters are hand-fed, additional feed should be supplied the pigs by means of a creep, as soon as they are 1 to 2 weeks old. A creep is an enclosure in a corner of the paddock or pen, with openings of such size that the pigs can run in and out, while the sows are excluded. Here the pigs are provided palatable concentrates, in either a small trough or a small self-feeder.

For use in a pen of a central hog house, where space is limited, a creep-feeding trough can be used. Such a

trough has a cover extending out far enough so the sow cannot get at the feed, while the pigs can reach it beneath the cover.

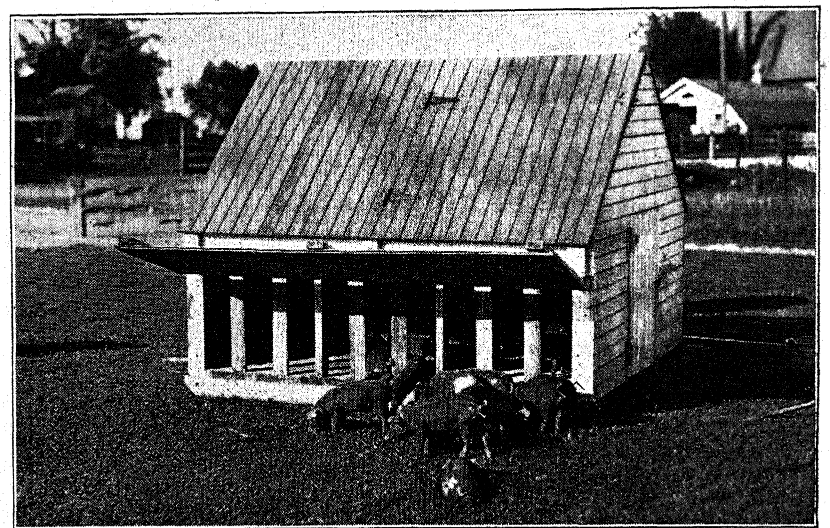
Creep-feeds are often called "pig starters." Suitable mixtures for creep-feeding are given in Appendix Table VII.

The purpose of creep-feeding is to supply the young pigs with as great an amount of nutrients as possible during this period of very efficient growth. Therefore the creep-feed should be highly palatable to them. Several experiments have been conducted to compare the results from various creep-feeds, or pig starters.[47]

These have shown that young pigs do not like a very fine, dusty mixture, and they prefer shelled or cracked corn to that which is ground fine. One good method of creep-feeding is to supply separately shelled corn and an efficient protein supplemental mixture, free-choice. Good ingredients in such a supplement are soybean oil meal, meat scrap, fish meal, and dried dairy by-products.

For pigs not on pasture a pig starter should contain 2.5 to 5 per cent of high-quality alfalfa meal and an antibiotic supplement. There may be no advantage from including an antibiotic supplement in a pig starter for pigs running with their dams on good pasture.

Oat groats, or hulled oats, are very palatable to young pigs and are an excellent ingredient in pig starters. Adding 10 per cent of cane sugar or cane molasses to a complete starter usually increases the palatability somewhat. In some tests pelleted starters have given slightly better results than starters in meal form, but not in other trials.



A COLONY HOUSE ARRANGED AS A CREEP

Here the young pigs get additional feed and are also provided with shelter and shade.

Where skimmilk or buttermilk is available, little or no other protein supplements are needed. Shelled corn and sufficient of one of these dairy by-products make an excellent combination.

1481. Weaning time.—When only one litter of pigs is raised a year, the pigs may run with their dam 10 to 12 weeks, or the sow may be allowed to wean the pigs herself. However, when 2 litters are raised yearly the pigs must be weaned not later than the age of 7 to 8 weeks, as sows do not commonly come in heat until after their pigs are weaned.

When the litters are to be weaned at this age, the amount of concentrates fed the sows should be reduced for a few

days before weaning, in order to check the milk flow. If the sows and litters have been self-fed on pasture, it is best to shut the sows away from the self-feeder by means of a creep 3 to 4 days before weaning. For this short period the sows will get enough nourishment from the pasture. If a sow's udder becomes unduly distended with milk after she is taken away from her pigs, it may be necessary to return her to the pigs for a few minutes every second day until she dries off.

It is especially important that clean pasture, free from contamination with round worms and other parasites, be provided for the pigs after weaning. If there is much difference in the ages of the various litters, it is best to group them according to size, subdividing a pasture, if necessary. Pigs will do best if there are not over about 20 in a group, as there is then less crowding in the colony house on cold nights. However, a much greater number may be successfully kept in a large pasture, if self-feeders and colony houses are well distributed, instead of all being located at one point.

Since the pigs no longer get their mother's milk, the ration after weaning should contain a larger proportion of protein-rich feeds than before. For weanling pigs in dry lot, the ration should have at least 18 per cent protein. (**1388**)

Several rations for pigs after weaning and also at later ages are given in Appendix Table VII. These will serve as convenient guides in selecting suitable combinations under the conditions in any particular locality.

Rations for weanling pigs should, if possible, include a protein supplement of animal origin, such as meat scrap, tankage, fish meal, or dairy by-products. A liberal amount of skimmilk or buttermilk, fed with grain, is unexcelled at this time.

Where no fluid skimmilk or buttermilk is available, weanling pigs in dry lot will usually make slightly more rapid gains when a little dried skimmilk, dried buttermilk, or liver meal is added to such a ration as corn and a trio mixture. (**894, 913**) Owing to the usual high prices of these feeds, such an addition may not be economical for pigs being raised for market, while it may be desirable in raising purebred breeding stock.

As is shown in the preceding chapter, the gains of young pigs are generally appreciably increased and the feed efficiency slightly improved when an antibiotic-vitamin B_{12} supplement is added to a good ration. (**1422**) The needs of pigs for the various vitamins and the use of supplements supplying B-complex vitamins and other vitamins have been previously discussed in detail. (**1406–1420**)

1482. Weaning pigs early.—During recent years there has been considerable interest in weaning pigs before the usual age of 7 to 8 weeks. Under some conditions early weaning has definite advantages, but it also has certain limitations and disadvantages.

Weaning at 3 weeks of age is generally successful with thrifty, vigorous pigs, if they are fed a special dry ration, and particularly if the care and management are much better than usual.[48]

Weaning at an earlier age is not practical under most conditions.[49] If pigs are weaned at only a few days of age, they must be fed an expensive milk replacer in liquid form, and even then the results may be inferior to later weaning.

Feeding the reconstituted milk replacer requires additional bother and labor. Also, very strict cleanliness of troughs and equipment is essential. Most milk replacers contain considerable dried skimmilk or other dried milk by-products, and must be completely reinforced with vitamin and mineral supplements, as well as with an antibiotic-vitamin B_{12} feed supplement.

Weaning at 3 weeks of age aids in securing 2 litters a year, especially with sows that farrow late in the spring. With unusually careful management 5 litters may even be obtained in 2 years. When spring litters are weaned at 3 weeks, the sows to be sold can be marketed earlier in the season, when the price is often better than later.

Pigs that are to be weaned at 3 weeks should be creep-fed, while they

are with the sows, the same dry mixture that will be used later. This may consist mostly of an efficient pig starter, but at least one-quarter of the mixture should be a more expensive, completely reinforced milk replacer.

In Minnesota trials pigs weaned at 3 weeks made nearly as rapid gains as those which nursed the sows 8 weeks.[50] Up to 8 weeks of age, the feed cost per pound of gain, including the feed eaten both by the pigs and by the sows, was slightly higher for the early-weaned pigs.

In an Illinois experiment pigs weaned at 20 days of age gained 0.32 lb. a day to 7 weeks, in comparison with 0.41 lb. for pigs which were not weaned until that old.[51] The feed cost per pig, including the feed of pigs and sows, was higher for the pigs weaned early.

1483. Milk replacers, or prestarters.—Many experiments have been carried on during recent years in endeavors to develop milk replacers, or prestarters, which would successfully replace sow's milk for early-weaned pigs.[52] A milk replacer must be fed in reconstituted warm liquid form, or as a gruel, at least during the first few days.

The successful milk replacers commonly contain a considerable proportion of dried skimmilk or other dried dairy by-products, and also such cheaper feeds as ground oat groats (without the hulls), ground corn or other grain, dehydrated alfalfa meal, soybean oil meal, meat scrap, fish meal, and other protein supplements. Often the mixture contains sugar (glucose, lactose, or cane sugar) or cane molasses, and a small percentage of added fat. The milk replacer should be well fortified with complete mineral and vitamin supplements and with an effective antibiotic.

Several of the larger formula feed manufacturers make such milk replacers. Because of the complexity of the formulas, milk replacers are not adapted to mixing on the farm.

The early weaning of pigs has been discussed in the preceding article. While the removal of pigs from the sows at only a few days of age is sometimes recommended, this is apt to result in poorer growth and greater death losses than weaning them when 3 weeks old or more.

The formulas for certain milk replacers which have given good results in experiment station trials are stated in Appendix Table VII.

1484. Pig hatcheries.—A few farmers have specialized in the large-scale production and sale of weaned pigs, usually about 8 weeks old.[53] Such enterprises are often called "pig hatcheries."

With excellent equipment and most expert care and management, the number of pigs raised per litter may be considerably greater than on most farms, thus reducing the cost per weaned pig. Usually early weaning is practiced, so that at least 2 litters a year can be produced per sow.

The financial returns from pig hatcheries have varied widely. In some cases such enterprises have been given up because of poor results due to serious disease outbreaks, or to lack of the skillful management necessary in such an undertaking.

1485. Growing and fattening pigs.—To produce rapid and cheap gains, growing and fattening pigs must receive well-balanced rations that provide a sufficient amount of protein and also protein of good quality. Likewise, care must be taken that their mineral and vitamin needs are fully met, which have been discussed in the previous chapter. Several example rations for pigs in dry lot and also for those on pasture are given in Appendix Table VII. The values of the various grains and other concentrates are discussed in the chapters of Part III.

Whenever possible, good pasture should be provided for growing pigs, on account of the advantages that have been emphasized previously. When pigs cannot be on pasture, legume hay should be included in their ration as insurance against a deficiency of vitamins. (**1417**) For pigs not on pasture it is important to use an efficient protein supplement, such as discussed in the preceding chapter. (**1418–1420**)

Whether to fatten spring pigs for market early in the fall by self-feeding

them concentrates on pasture, or to force them to consume more pasture by restricting their concentrate allowance, will depend on the relative prices of grain and pasture, and the prices for pork at the various times in the fall and winter, as has been shown previously. (1432)

Detailed information has been given in the preceding chapter on the effects on the carcass and on the feed efficiency of feeding a limited ration to fattening pigs. (1429–1432)

Pigs should always be provided with an abundance of fresh water in a trough or an automatic waterer. If self-feeders and automatic waterers are used, it should be borne in mind that even with these labor-saving devices one cannot expect success if he does not give the proper attention to his pigs. One should see daily that the feeders and waterers are working properly and should clean them out when necessary.

If the pigs are on first-class pasture and are fed such supplements as skimmilk, tankage, or fish meal, there is probably little or no advantage in feeding any other mineral supplement than salt. However, for pigs not on good pasture, feeding a simple mineral mixture, such as has been recommended before, may be advisable, even when protein supplements of animal origin are used.

1486. Artificial light.—Since artificial light at night increases the egg production of hens in winter, it was suggested that it might increase the feed consumption and the gains of self-fed fattening pigs. However, in an Illinois trial and a Minnesota test, light turned on automatically for 2 periods at night did not significantly affect feed consumption or gains.[54]

1487. Raising breeding stock.—Pigs selected for the breeding herd, both sows and boars, should be fed so they will develop good size and strong bone, but should not be allowed to become as fat as pigs that are being finished for market. If the spring pigs are fed a limited allowance of concentrates on good pasture and receive a well-balanced ration, it may not be necessary to separate the gilts to be retained for breeding from the other pigs until full-feeding is started in the fall.

On the other hand, if the pigs intended for the market are being fattened as they grow by self-feeding or by hand-feeding them all they will eat, it is best to separate the breeding stock soon after weaning, so they may be fed a ration suited to their needs. However, if the pigs are being fed a well-balanced ration and are of a growthy type, the gilts may be safely kept with the market pigs until they reach a weight of 125 to 150 lbs. After this, the amount of concentrates should be limited, so the gilts will not get too fat.

Special care should be taken that the ration for pigs being raised for breeding stock contains sufficient protein and protein of good quality, and that there is an abundant supply of calcium, phosphorus, and vitamins. Such pigs should be on good pasture during just as much of the year as is possible. This is the best insurance against any lack of vitamins. When pasture is not available, 10 to 15 per cent of legume hay should be included in the ration.

Breeding swine may be raised with success on grain (even corn) as the chief concentrate, if the grain is properly supplemented and if the amount is limited so that the pigs do not get too fat. However, most breeders prefer concentrate mixtures containing at least 25 to 30 per cent of such bulky feeds as ground oats, wheat bran, or standard middlings. If possible, some protein-rich feed of animal origin should be included in the ration, such as meat scrap, tankage, fish meal or dairy by-products. This is especially important if the pigs are not on first-class pasture.

If plenty of skimmilk or buttermilk is fed, an excellent combination is one-half to two-thirds corn, barley, or grain sorghum, with the remainder oats or standard middlings and with pasture or legume hay in addition.

Sows and boars of the larger breeds should reach a weight of 350 lbs. or more at one year of age, if properly fed and managed.

In a Minnesota trial fall-farrowed

gilts were fed a limited ration in winter and also on pasture the next summer, in comparison with full-fed gilts.[55] When they farrowed in the fall, the limited-fed gilts weighed an average of only 304 lbs. and had eaten 959 lbs. of feed per head, in addition to pasture. The full-fed gilts averaged 429 lbs. and had consumed 1,632 lbs. of feed. The liberally-fed gilts farrowed an average of 1.2 more pigs per litter, and their pigs weighed 4.2 lbs. more per head at weaning.

In Washington and Wisconsin experiments gilts raised on limited rations reached puberty slightly earlier than did those fed liberally.[56]

1488. Age to breed gilts.—Gilts are generally bred so that they will farrow when about a year of age. However, purebred gilts that are intended for a show herd are often not bred until they are somewhat older, so that they will reach a larger size.

It was proved many years ago by extensive experiments at the Missouri Station that breeding well-fed sows in successive generations to farrow at less than a year of age was not injurious and did not reduce their mature weights.[57] Sows that were bred early were only slightly smaller at 20 months than later-bred sows, and they finally became fully as large.

When early and frequent breeding was combined with scanty feeding, the sows did not reach normal size. This checking of growth was due to the heavy drain on the sows when they were fed scantily during lactation.

The pigs in the first litters of young sows are slightly smaller at birth than those from older sows, and they also make a trifle less rapid gains. In commercial pork production this is much more than offset by the additional cost of maintaining a later-bred sow for a longer period before she produces her first litter.

1489. Two litters vs. one litter a year.—Whether it will be more profitable to follow the two-litter-a-year method of pork production or to use the one-litter system will depend on the local conditions, especially on the winter climate and on the shelter and feed that can be provided.

When the one-litter system is followed, the pigs are nearly all farrowed in the spring and few or no sows are bred for fall pigs. Commonly, gilts are used chiefly or entirely in this system, and in the summer after they have weaned their first litters they are fattened for market. Only gilts are used, because it does not pay to maintain an older sow an entire year to raise only one litter.

Under the two-litter system; the sows are bred to farrow sufficiently early in the spring so that the fall litters can get a good start on pasture before cold weather comes on. Sows usually come in heat a few days after their litters are weaned, but not during the suckling period. Since the fall litters should be farrowed by September, this means that the spring litters must come not later than March. Raising two litters a year should therefore not be attempted in the North unless these early pigs can be given proper shelter and care.

Even when an endeavor is made to raise two litters a year from all the sows possible, there will usually be more spring litters than fall litters. Often, some of the spring-farrowing sows will not become pregnant from the first service, and then it may be too late in the season to breed them again for fall litters. Under this system, however, it is easily possible to raise an average of three litters every two years.

Where the climate is mild, the two-litter system is usually decidedly more profitable than the one-litter method. The fall litters should prove as satisfactory as the spring pigs, for they can be furnished pasture until late in the fall and in the southern states also in winter. Even in the northern states, excellent results are secured from fall pigs when they are properly fed and cared for.

In the corn belt the two-litter system has several advantages, as well as certain disadvantages. The chief advantages are: (1) A maximum use is made of capital invested in equipment; (2) the breeding herd may be improved more readily by

retaining sows that produce large litters of pigs that prove efficient in the feed lot; (3) there is a better distribution of labor; (4) under the two-litter system pigs can be marketed at the two times of the year when the prices are usually highest—in early fall and in spring; and (5) there is a better distribution of farm income.

These advantages are offset to some extent by the fact that the death losses are usually higher in pigs farrowed early in the spring, as is necessary in the two-litter system, than they are in litters farrowed later when the weather is more favorable.

In cost studies on Illinois, Indiana, and Minnesota farms and in South Dakota experiments during 5 years, the two-litter system was more profitable than the one-litter method.[58] The possibilities for increased profits with the two-litter system under careful management are well shown by the results of the South Dakota studies. On the average, the net return per sow was $110.70, in comparison with only $42.14 per sow in the one-litter method.

1490. Fall pigs.—Even in the northern states pigs which are farrowed early in the fall and which get a good start on pasture make satisfactory and economical gains. However, under poor conditions fall pigs are apt to be a disappointment where the winters are cold.

In Minnesota trials fall pigs that were well housed and fed efficient rations in dry lot from shortly after weaning required 404 lbs. of feed per 100 lbs. gain; spring pigs fed in dry lot, 402 lbs.; and spring pigs on pasture, 390 lbs. not including the pasture eaten.[59] Because of a higher price per hundredweight, the net return was considerably greater from the fall pigs.

In South Dakota experiments over a period of 5 years, fall pigs required an average of 446 lbs. of feed, including that eaten by the sows, per 100 lbs. of pork produced.[60] For spring pigs the requirement was 413 lbs. of concentrates, in addition to pasture. The net return per 100 lbs. of pork produced was higher for spring pigs.

In the South where pasture can be provided during all or most of the winter and where the weather is hot in summer, fall pigs may make more rapid and more economical gains than spring pigs. This was the case in Tennessee experiments with pigs which were either full-fed or fed limited rations on pasture.[61] Fall pigs also made more rapid gains than did spring pigs in Texas trials, but the fall pigs needed about 9 per cent more feed per 100 lbs. gain.[62]

Where the winters are cold, fall pigs should be farrowed early enough to be well started before the cold comes on. It is important that clean pasture be provided for sows with fall litters, as this aids greatly in keeping the pigs thrifty. Where the climate is suitable, the pigs should also be on good pasture at weaning time and for as long afterward as possible. This will enable them to build up a store of vitamins in their bodies to help overcome any shortage during the winter.

To keep fall pigs thrifty after the pasture season and to secure rapid and economical gains, they must receive efficient rations. The importance has been emphasized in the previous chapter of feeding pigs in dry lot rations that provide: (1) Plenty of protein; (2) protein of good quality; (3) ample minerals; and (4) an abundant supply of vitamins. As shown previously, it is especially important to include well-cured legume hay as vitamin insurance in rations for growing pigs not on pasture.

Efficient supplemental mixtures for growing and fattening pigs in dry lot have been discussed in detail in the preceding chapter (**1418–1420**) An antibiotic-vitamin B_{12} feed supplement increases the gains and helps keep the pigs thrifty. (**1422**)

If plenty of skimmilk or buttermilk is available, the ration for fall pigs may consist of only grain and the dairy by-product, with legume hay in addition. For pigs under 75 lbs. in weight it is advisable to add to a ration of corn, skimmilk, and legume hay a small amount of some other protein supplement, as young pigs full-fed on corn will often not drink

enough milk to balance the ration completely.

Suitable, well-ventilated dry quarters must be provided for fall pigs, where they can be kept comfortable during cold, wet weather. They should be supplied with sufficient bedding, and this should be replaced when it becomes damp.

1491. Sanitation and disease prevention.—Sanitation is fully as important as proper feeding in pork production. If hogs are raised on the same ground year after year with little or no regard for proper sanitation, there will be heavy losses from round worms and other parasites and also from filth-borne diseases. As a result of these conditions, many pigs will die before they get to market, and others will become unprofitable. On the other hand, under an efficient system of swine sanitation, including the use of clean, uncontaminated pasture for the young pigs, such losses can be largely prevented.

The common round worm of swine is one of the chief causes of death or lack of thrift among young pigs, and also is one of the most injurious parasites in older swine. Under usual conditions, probably one-third of the hogs of breeding age are infected to a greater or less extent with these parasites.

It is difficult to control round worms, because the eggs, which are voided in the feces from infected swine, are resistant to freezing, thawing, or drying and also are not killed by most chemical disinfectants. However, they are soon killed by exposure to sunlight in a dry place.

The "McLean County System of Swine Sanitation," developed by the United States Department of Agriculture, not only controls round worms but also largely prevents trouble from other internal parasites and from filth-borne diseases, such as necrotic enteritis.[63] The effectiveness of this system is based upon the fact that when the round worm eggs are first passed out of the body of a hog in the feces they are not infectious. In a few weeks or longer, tiny worms develop in the eggs. If then swallowed by swine, the eggs will hatch and the worms will infect the swine.

The eggs are of microscopic size and are present in the manure of infected hogs or in soil contaminated by such manure. One full-grown female worm may produce as many as 80,000,000 eggs. The eggs may remain alive in the soil for a year or more.

The incubated eggs which are swallowed by pigs hatch in the small intestine. The young worms, which are too small to be seen by the naked eye, then penetrate the wall of the small intestine and are carried in the blood through the liver to the heart and lungs. In the lungs the small worms migrate through the blood vessels and invade the lung tissues. From the air spaces in the lungs, the worms are coughed up by the pigs into the throat and swallowed. The worms, which are now only one-fifteenth to one-twentieth inch in length, grow to adult size in the intestines in a period of 2 to 3 months.

The greatest injury to young pigs occurs when the worms are in the lungs. In case of a heavy invasion, many abcesses are produced, the pigs become unthrifty, and many die from pneumonia. Common indications of infestation are coughing and difficult breathing, sometimes known as "thumps." In the later intestinal stages, the worms may also be decidedly injurious if many are present. This is especially the case when they invade the gall bladder and the ducts of the liver.

The following are the essentials of the McLean County system:

1. The farrowing pens should be cleaned thoroughly, all dirt, dust, and bedding being removed. Then the floors and the walls for 2 feet from the floor should be scrubbed with boiling water, to each 30 gallons of which 1 lb. of lye has been added. After the pen has been scrubbed it is wise to spray it with a reliable disinfectant. The lye does not kill the round worm eggs, but is necessary to loosen the dirt, and thus remove the eggs. The hot water kills some of the eggs and the lye and the disinfectant kill disease germs.

2. Before the sow is put in the farrowing pen, all dirt and litter should be

carefully brushed from her sides and legs, and her udder, legs, and feet washed with warm water and soap. A single small chunk of dirt remaining on the sow may contain enough round worm eggs to stunt a pig that swallows it.

3. Until they are taken to pasture, the sow and pigs must be confined to the farrowing pen, or to the pen and a paved adjacent outside lot which has been similarly scrubbed. The sow and litter should

SCRUBBING THE PEN

In the McLean County system of sanitation, the farrowing pen is scrubbed with a hot lye solution.

be hauled (not driven) to a pasture where no pigs have been kept for at least a year, and which preferably has been cultivated since it was last used by hogs. If the pigs are driven over contaminated ground, they may pick up enough worm eggs on the way to lessen greatly the benefits from the system.

4. The pigs should be kept on clean pasture until they are at least 4 months old, after which time they are much less susceptible to injury from round worms or other parasites, or to infection with necrotic enteritis or other filth-borne diseases.

Where the soil is sandy and well-drained it may not be necessary to wash the sows before farrowing. Also, when sows farrow during the pasture season, they can be housed in portable colony houses located in the clean pasture where they are to remain after farrowing. The floor of the colony house should, of course, be cleaned and scrubbed as advised in the case of the farrowing pen.

The benefits from following an efficient system of swine sanitation are shown by studies which have been made of the cost of pork production on various farms. For example, on Illinois farms where the McLean County system was followed, 55 lbs. less feed was required per 100 lbs. gain than on farms where no sanitation system was used, and the total cost per 100 lbs. of hogs marketed was 19 per cent less.[64]

Even when good sanitation is followed, some pigs may become infected with round worms. In all such cases a reliable worm expellant should be used. Care should also be taken to eradicate lice by greasing, spraying, or dipping swine with crude oil or waste crank case oil. Mange should be eradicated by treatment with crude oil, or kerosene mixed with lard or cottonseed oil, or lime sulfur solution.

Where hog cholera is common, the only safe plan is to immunize all swine by vaccination.

1492. Shipment to market; shrinkage.—To reduce the shrinkage in weight of hogs during shipment to market certain precautions should be taken. Indiana studies show that where hogs are trucked not over about 100 miles to market and can be fed after arrival, it is best to give them a normal feed the previous evening, but not to feed them at the farm the morning of shipment.[65] They should be hauled to market early in the morning and be given a corn and water fill at the market.

Hogs shipped a longer distance should be fed grain before shipment.[66] However, they should be given only a rather light feed, especially in hot weather, so they will be less apt to overheat.

Because they are accustomed to unground corn, hogs that are finished on shelled corn or ear corn are apt to fill better on shelled corn and water at the market than those which have had ground feed. It is probably not advantageous to confine pigs that have been on pasture to a dry lot for a few days

before shipping them. This may reduce the shrinkage between home weights and market weights, but some shrinkage will have already occurred in the change from pasture to dry lot. If hogs have been fed slop, it may be wise to use dry feed for a few days before shipment.

In driving or loading the hogs, care must be taken not to hurry or excite them, and they should not be beaten or bruised. Crippled hogs sell at a severe discount, and bruises also lower the selling price, as they injure the carcass.

When hogs are shipped by rail, they should reach the shipping station in plenty of time for them to become rested and cooled before they are loaded. The car should be thoroughly cleaned before loading and should be bedded with sand, as this furnishes better footing than straw or than no bedding at all.[67] In hot weather hogs should be sprayed with a hose before loading and also when possible at stopping points in transit. If the weather is very hot, suspending from the roof of the car sacks containing large cakes of ice, helps prevent overheating. In extreme winter weather it is a good plan to protect the hogs from cold winds by nailing a few strips of building paper on the inside of the car.

Indiana experiments show that the shrinkage is increased when a car is loaded too full.[68] However, if there are not enough hogs to fill it comfortably when they are lying down, the shrinkage will also be greater, because of jostling around.

The average percentage of shrinkage for hogs shipped by rail for various distances in the Indiana studies ranged from 1.35 per cent for those shipped less than 62 miles, to 1.89 per cent for those shipped 263 miles or more. The percentage of shrinkage was somewhat greater for heavy hogs than for lighter ones, probably because heavy hogs cannot handle themselves so well and they tire more easily. Also, they may not fill so well at the market.

In studies by the United States Department of Agriculture, the shrinkage was determined between the purchase weights of hogs bought by packers at shipping points in the country and the shrunk weights after shipment to the packing plants.[69] Hogs in transit 7 to 12 hours shrank an average of 5.3 per cent in summer and 4.1 per cent in winter. Those in transit 55 to 60 hours shrank 8.9 per cent in summer and 7.9 per cent in winter.

Most of the shrinkage is due to excretion of feces and urine, but part is due to actual tissue shrinkage. It was estimated that the tissue shrinkage was less than 1 per cent of the live weight for hogs in transit 7 to 12 hours, and about 3 per cent for hogs in transit 55 to 60 hours.

It was found in the Indiana studies that the shrinkage increased as the temperature rose, except that the shrinkage was also higher when the temperature was less than 18 to 27° F. The shrinkage was lowest in late fall and in winter when the hogs had been fattened on dry feeds. It was greatest in spring when pasture was lush, and in early fall when a large proportion of the hogs had probably been finished on new corn. The percentage shrinkage of hogs is considerably greater in mixed carloads of hogs and other stock than it is in straight carloads of hogs.

In Illinois studies there was no marked difference in percentage of shrinkage when hogs were shipped the same distance by rail and by truck, though there was a tendency for the shrinkage to be slightly higher for truck shipment.[70] The losses by death and crippling were only about one-half as great in Indiana studies for hogs trucked (usually less than 75 miles), as they were for hogs shipped by rail (generally 75 to 175 miles).[71] Part of this difference was, of course, due to the greater distance of the rail shipments.

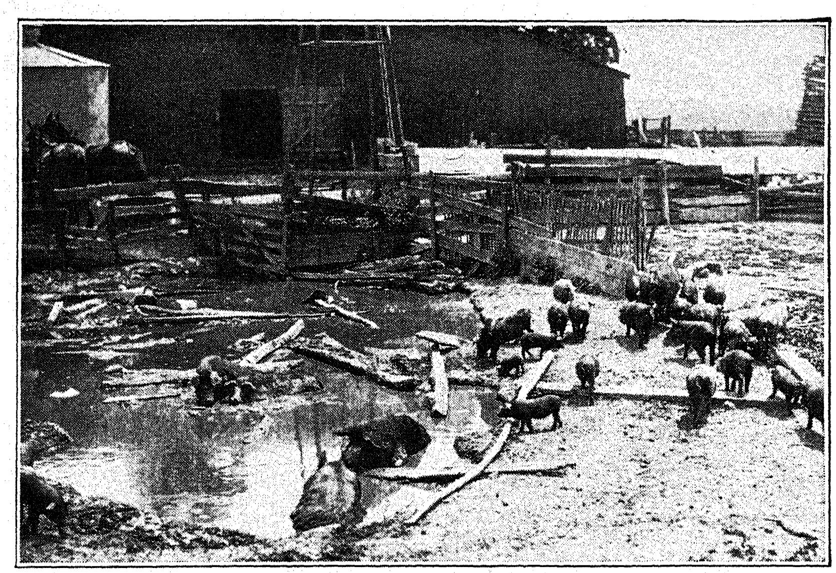
1493. Cost of pork production.— The cost of producing pork will vary widely from year to year and also during the same year in various sections, depending chiefly upon the prices of feed. The cost of feed, including pasture, will commonly form 75 to 85 per cent of the total cost of producing 100 lbs. of marketable hogs. Man labor, the next largest

cost, is usually less than 10 per cent of the total cost. To the cost of feed and man labor must be added the expenses for horse or tractor labor, equipment and shelter, interest, veterinary services, and miscellaneous items, including death losses.

In extensive cost accounting studies on farms in various corn belt states a total of 428 to 505 lbs. of concentrates has been required, on the average, in producing each 100 lbs. of marketable live hogs.[72] This includes the feed eaten by the breeding herd, but does not include hay or pasture consumed. Skimmilk fed on some of the farms has been reduced to an air-dry basis.

In Illinois studies there were required per 100 lbs. of marketable live hogs: 400 lbs. corn, 73 lbs. other grain, 7.7 lbs. miscellaneous concentrates, 2.0 lbs. hay, and 1.5 lbs. minerals, or a total of 484 lbs., including hay.[73] In studies in southeastern Minnesota, a dairy district where skimmilk was fed on many of the farms, the average requirement per 100 lbs. of marketable hogs was: 316 lbs. corn, 124 lbs. other grain, 14 lbs. other concentrates, and 459 lbs. skimmilk.[2]

In the Illinois studies the total cost of producing each 100 lbs. of marketable hogs was equal to 11.1 times the average farm price of corn per bushel. This relationship, called the corn-hog ratio, varies considerably in various years, depending on the price of corn compared with the level of other costs. For example, in studies by the United States Department of Agriculture when corn was very cheap, the cost of producing 100 lbs. of hogs was 15.2 times the farm price of corn per bushel.[74]



UNDER THESE CONDITIONS PROFITS CANNOT BE EXPECTED

Pigs which have no pasture and are in filthy, unsanitary quarters make expensive gains. Many become runts or die because of disease or infection with worms.

On the Illinois farms the sows in the breeding herds consumed an average of 2,075 lbs. of feed per head in addition to pasture during the year. On many of the farms gilts were used solely or chiefly for breeding, and these were sold as soon as they could be fattened after weaning their first litters.

In these studies approximately 30 per cent of the total cost of producing pork was for the maintenance of the

breeding herd and 70 per cent for the growing and fattening pigs.

1494. Reducing the cost of pork production.—These cost studies and also similar other investigations show clearly the ways in which the cost of pork production may be reduced and the net returns increased on the average farm.[75]

One of the most important factors is the average number of pigs raised per litter. When the number weaned per litter is small, the pigs will start into the fattening period with a cost handicap that cannot be overcome by the most efficient feeding and care. In the Minnesota studies, the average net return over cost of feed, per 100 lbs. of hogs marketed, was $1.70 on farms where an average of 7 pigs or more were weaned per litter, and only 80 cents on farms where the average number weaned was 5 or less.[2]

Large litters at weaning time can be secured only by a combination of efficient breeding and selection of breeding stock, the feeding of excellent rations to brood sows and young pigs, and proper housing and care of the sows, including the use of guard rails or pig brooders to protect the young pigs.

Other factors of prime importance in increasing the net returns from pork production, which have been emphasized previously in this and the preceding chapter, are: Providing good pasture throughout the growing season; efficient control of internal parasites and certain diseases by sanitation; the feeding of economical well-balanced rations to growing and fattening pigs; and planning the swine enterprise so that the hogs are ready for market at the times of the year when prices are best.

THRIFTY PIGS RAISED UNDER SANITARY CONDITIONS

These thrifty pigs on clean alfalfa pasture are a striking contrast to those in unsanitary quarters.

The importance of abundant good pasture for swine is shown by the records on 200 Illinois farms.[76] On the one-third of the farms where the most pasture was provided only 417 lbs. of concentrates were required per 100 lbs. of hogs marketed. On the farms having the least pasture, the requirement was 462 lbs. of concentrates.

The best returns are, of course, secured by highly efficient farmers who excel in all the ways of reducing the cost of

production. For example, in the Minnesota studies farmers who excelled in all the factors necessary for low cost pork production, received a net income over cost of feed of $2.79 on each 100 lbs. of hogs marketed.[2] Those who excelled in only half the important factors received a net income of only $1.49 per 100 lbs. of hogs marketed, and those who were below average in all factors did not get enough income from their hogs to pay for the cost of feed.

In a recent cost study of pork production on Iowa farms, only 58 per cent as much feed was required to produce 100 lbs. of live hogs on the one-third of the farms that were most efficient as was needed on the least efficient one-third.[77]

QUESTIONS

1. Discuss the importance of pasture for swine.
2. What are the best pasture crops for swine in your region?
3. What do the Minnesota cost studies show concerning the value of pasture?
4. What results have been secured in experiments in which growing and fattening pigs on pasture have been compared with those in dry lot?
5. What factors should be considered in selecting brood sows and boars?
6. State 6 essentials in the feed and care of brood sows.
7. What grains are most commonly fed to brood sows in your region?
8. Discuss the feeding of brood sows on grain alone during pregnancy.
9. Why is it important to feed legume hay to brood sows not on pasture?
10. Discuss the use of legume hay as the only protein supplement for sows.
11. Which protein-rich feeds are satisfactory as the only protein supplement for brood sows? Which protein supplements should be fed in combination with more efficient supplements?
12. Discuss the use of corn for brood sows. How do barley and oats compare with corn in value for sows?
13. Under what conditions should other mineral supplements than salt be fed to brood sows?
14. How would you regulate the amount of grain for pregnant sows? Is it generally advisable to self-feed pregnant brood sows?
15. Discuss the importance of exercise for brood sows.
16. How should brood sows be fed during the summer?
17. Why is it advisable to "flush" sows shortly before breeding time?
18. State the most important points concerning the feed and care of the boar.
19. What are the advantages and disadvantages of gilts in comparison with older sows?
20. State briefly how you would feed and care for a sow: (a) Previous to farrowing; (b) at farrowing time; (c) immediately after farrowing.
21. About how much milk does a good sow produce during a lactation period?
22. How are litters "evened up?"
23. Discuss the feeding of sows that are suckling litters.
24. What sort of a feed should be used for creep-feeding suckling pigs?
25. Discuss the early weaning of pigs.
26. What feeds and supplements should a milk replacer contain?
27. Are there any pig hatcheries in your state? How successful have they been?
28. Discuss the feeding and care of pigs and sows at weaning time.
29. In what respect should the feeding of pigs which are being raised for breeding stock differ from that of pigs which are being fattened for market?
30. What have experiments shown concerning the effects of breeding gilts at an early age?
31. State the advantages and disadvantages of the two-litter-a-year method of pork production in comparison with the one-litter method.
32. How do fall pigs compare with spring pigs in rate and economy of gains, when properly fed and cared for?
33. What are the essentials for success with fall pigs?
34. Discuss the importance of sanitation and disease prevention in pork production.
35. Describe the McLean County system of round-worm control, stating the facts in the life history of the round worm upon which the effectiveness of the system depends.
36. What precautions would you take to reduce the shrinkage when hogs are shipped to market?
37. Discuss the main factors in the cost of pork production.
38. What are the ways in which the cost of

pork production may be reduced on the average farm?

REFERENCES

1. Hughes and Hart, Cal. Bul. 616; Wright and Fenn, S.D. Rpt. 1942.
2. Nodland and Pond, Minn. Bul. 379.
3. Ga. Coastal Plain Cir. 19; Aubel and Connell, Kan. Cir. 188; Willman, Sheffy, and Morrison, N.Y. Farm Res., 19, 1953, No. 4; Robison, Ohio Anim. Sci. Mimeo. Ser. 86; Smith, Cole, and Hobbs, Tenn. Farm and Home Sci., Prog. Rpt. 3; Carroll and Krider, Swine Production, 1950, p. 382.
4. Willman, Sheffy, and Morrison, N.Y. Farm Res., 19, 1953, No. 4.
5. Morrison and Bohstedt, Wis. Bul. 302; Morrison, Bohstedt, and Fargo, Wis. Bul. 362; see also: Grimes, Penn. Bul. 168.
6. Vestal, Ind. Rpt. 1933.
7. Hughes, Cal. Sta., Jour. Agr. Res., 49, 1934, pp. 943–953; Doyle, Ind. Rpts. 1939, 1940; Thompson, Okla. Bul. 144.
8. Vestal, Ind. Bul. 413.
9. Grimes, Penn. Bul. 168.
10. Martin, Ark. Bul. 221; Evvard, Iowa, Amer. Soc. Anim. Prod., Proc. 1913; Freeman, Mich. Quar. Buls., 21, 1938, No. 2; 25, 1942, No. 2; Weaver, Mo. Bul. 340; Snyder, Nebr. Bul. 147; Grimes, Penn. Bul. 168; Penn. Bul. 204.
11. Freeman, Mich. Quar. Bul., 21, 1938, No. 2.
12. Freeman, Mich. Quar. Bul., 25, 1942, No. 2.
13. Morrison and Bohstedt, Wis. Bul. 302; Morrison, Bohstedt, and Fargo, Wis. Bul. 362; Morrison, Fargo, and Bohstedt, Wis. Bul. 400.
14. Vestal, Ind. Rpts. 1939, 1940, 1941.
15. Wash. Bul. 187.
16. Hart and Steenbock, Wis. Buls. 323, 339, and Jour. Biol. Chem., 39, 1919, pp. 209–233.
17. Conrad and Beeson, Ind., Jour. Anim. Sci., 14, 1955, pp. 1198–1199.
18. Evvard, Wallace, and Culbertson, Iowa Bul. 245.
19. Morrison and Fargo, Wis. Bul. 405; see also: Evvard, Culbertson, and Hammond, Iowa, Amer. Soc. Anim. Prod., Proc. 1922.
20. Evvard, Cox, and Guernsey, Iowa, Amer. Jour. Physiol., 34, 1914, p. 312; Hart and Steenbock, Wis., Jour. Biol. Chem., 39, 1919, pp. 209–233; Baskett, Agr. Progress, England, 3, 1926, pp. 34–36; Evans, Jour. Agr. Sci., England, 19, 1929, p. 752; Davidson, Jour. Agr. Sci., England, 20, 1930, p. 233.
21. Vestal, Ind. Bul. 413.
22. Terrill, Jensen, and Becker, Ill. Mimeo. Rpt. A.S. 417.
23. Self, Grummer, and Casida, Wis., Jour. Anim. Sci., 14, 1955, pp. 573–593.
24. Snyder, Nebr. Bul. 162.
25. Peters and Ferrin, Minn., mimeo. rpts.; Hale, Tex. Rpt. 1936; Morrison and Bohstedt, Wis., mimeo. rpts.
26. Hale, Tex. Rpt. 1937.
27. Vestal, Ind. Rpt. 1931; Anderson and Marston, Kan. Cir. 118.
28. Hanson, Nebr., Amer. Jour. Vet. Res., 12, 1951, pp. 118–122.
29. Smith, Pork Production, 3rd Ed., 1952.
30. McKenzie, Mo. Res. Bul. 118.
31. Vestal, Ind. Bul. 413; Weaver and Bogart, Mo. Bul. 461; Headley, Nev. Rpt. 1933; Kraft, Okla., Amer. Soc. Anim. Prod., Proc. 1929; Kuhlman and Cole, Wis. Bul. 405.
32. Lush and Molln, U.S.D.A. Tech. Bul. 836; see also: Craig et al., Ill. Mimeo. Rpt. A.S. 421.
33. Nordskog, Comstock, and Winters, Minn., Jour. Anim. Sci., 3, 1944, pp. 257–272; Kuhlman and Cole, Wis. Bul. 405.
34. Nodland and Pond, Minn. Bul. 379.
35. Wilcox, Carroll, and Hornung, Ill. Bul. 390.
36. Russell and Hutton, U.S.D.A. Cir. 472.
37. Newland et al., Mich., Jour. Anim. Sci., 11, 1952, pp. 118–133; see also: Orem, Taylor, Doyle, and Vestal, Ind. Rpt. 65.
38. Graham, Sampson, and Hester, Ill., Soc. Expt. Biol. and Med. Proc., 47, 1941, pp. 338–339; Ill. Cir. 557; Morrill and Sampson, Ill., Amer. Jour. Vet. Res., 13, 1952, pp. 327–329.
39. Hughes and Hart, Cal., Jour. Nutr., 9, 1935, pp. 311–322; Work, Henke, and Harris, Hawaii, Jour. Anim. Sci., 1, 1942, p. 72; Wells, Beeson, and Brady, Id. Bul. 236; Allen, Baker, and Lasley, Mo., Jour. Anim. Sci., 11, 1955, p. 1174; Thompson, Okla., Amer. Soc. Anim. Prod., Proc. 1931; Carlyle, Wis. Bul. 104; Bonsma and Oosthuizen, South Africa Jour. Sci., 32, 1935, pp. 360–378; Donald, Empire Jour. Expt. Agr., Great Britain, 5, 1937, pp. 349–360; Smith, New Zealand Jour. Sci. Tech., 34, 1952, pp. 65–75.
40. Carroll and Krider, Swine Production, 1950.
41. Hughes and Hart, Cal., Jour. Nutr., 9, 1935, pp. 311–328; Barnhart, Catron, and Culbertson, Iowa, Jour. Anim. Sci., 13, 1954, pp. 375–382; Parrish, Aubel, Wheat, and Hughes, Kan., Jour. Anim. Sci., 8, 1949, pp. 627–628; Davis et al., Okla., Jour. Nutr., 44, 1951, pp. 17–27; Heidebrecht, MacVicar, Ross, and Whitehair, Okla., Jour. Nutr., 44, 1951, pp. 43–50; Bowland, Grummer, Phillips, and Bohstedt, Wis., Jour. Anim. Sci., 32, 1949, pp. 22–28; 10, 1951, pp. 533–537; Sheffy et al., Wis., Jour. Anim. Sci., 11, 1952, pp. 727–735; Braude et al., British Jour. Nutr., 1, 1947, pp. 64–77; Beacom and Bowland, Canada, Jour. Nutr., 45, 1951, pp. 419–429; Perrin, New Zealand, Jour. Dairy Res., 21, 1954, p. 55.
42. Willet and Maruyama, Hawaii, Jour. Anim. Sci., 5, 1946, pp. 363–370.
43. Shepperd, N.D. Bul. 230.
44. Evvard and Glatfelder, Iowa Cir. 80.
45. Hawkins, Okla. Rpt. 1930–32; see also: Work, Henke, and Harris, Hawaii, Jour. Anim. Sci., 1, 1942, p. 72; Willman and Morrison, N.Y. (Cornell) Rpts. 1938, 1939.
46. Russell and Zeller, U.S.D.A. Farmers' Bul. 1504; Aubel and Connell, Kan. Rpt. 1930–32; see also: Carroll, Ill. Mimeo. Rpt. A.H. 1297.
47. McMillan and Wallace, Fla., Jour. Anim. Sci., 13, 1954, pp. 993–994; Krider, Terrill, Fairbanks, and Carroll, Ill., Jour. Anim. Sci., 9, 1950, pp. 157–162; Terrill, Meade, Nelson, and Becker, Ill., Jour. Anim. Sci., 11, 1952, p. 777; Notzold, Becker, Terrill, and Jensen, Ill., Jour. Anim. Sci., 14, 1955, pp. 1068–1072; Terrill et al., Ill. Mimeo. Rpts. A.S. 268, 324; Jensen, Launer, Terrill, and Becker, Ill. Mimeo. Rpt. A.S. 418; Lewis, Catron, Combs, and Ashton, Iowa, Jour. Anim. Sci., 12, 1953, p. 923; Nelson et al., Iowa Farm Sci., 7, 1953, No. 8; Lewis et al., Iowa, Jour. Anim. Sci., 14, 1955, pp. 1103–1115; Aubel, Kan. Cir. 258; Teague and Robison, Ohio Anim. Sci. Mimeo. Ser. 86.
48. Hanson, Minn. Farm and Home Sci., 12, 1955,

No. 2; Grummer and Whitehair, Wis. Bul. 511; Grummer and Self, Wis., Jour. Anim. Sci., 14, 1955, p. 1245.
49. Becker, Ullrey, and Terrill, Ill. Mimeo. Rpt. A.S. 270; Catron et al., Iowa, Jour. Anim. Sci., 12, 1953, pp. 62–76; Sheffy, Sewell, Eggert, and Loosli, N.Y. Farm Res., 19, 1953, No. 1; N.D. Bul. 380; Teague and Robison, Ohio Anim. Sci. Mimeo. Ser. 86; Wahlstrom, S.D. Farm and Home Res., 5, 1953, No. 1; Sheffy et al., Wis., Jour. Anim. Sci., 10, 1951, pp. 867–874.
50. Hanson, Minn. Farm and Home Sci., 12, 1955, No. 2.
51. Jensen, Terrill, and Becker, Ill. Mimeo. Rpt. A.S. 420.
52. Schendel and Johnson, Ill., Jour. Anim. Sci., 12, 1953, pp. 84–87; Becker, Ullrey, Terrill, and Notzold, Ill., Science, 120, 1954, p. 345; Becker, Ullrey, and Terrill, Ill. Anim. Sci. Mimeo. Rpt. A.S. 270; Catron, Nelson, Ashton, and Maddock, Iowa, Jour. Anim. Sci., 12, 1953, pp. 62–76; Hudman, Speer, Ashton, and Catron, Iowa, Jour. Anim. Sci., 14, 1955, pp. 1209–1210; Hogan, Anderson, Lasley, and Tribble, Mo. Bul. 584; Sheffy, Sewell, Eggert, and Loosli, N.Y. Farm Res., 19, 1953, No. 1; Wise, Barrick, Wise, and Osborne, N.C., Jour. Anim. Sci., 13, 1954, pp. 365–374; Teague and Robison, Ohio Mimeo. Series 86; Teague, Ohio Farm and Home Res. 290; Thompson, Whitehair, MacVicar, and Hillier, Okla. Misc. Pub. MP-27; Gobble and Miller, Penn. Bul. 502; Wahlstrom, S.D. Farm and Home Res., 5, 1953, No. 1; Crampton and Ness, Canada, Jour. Anim. Sci., 13, 1954, pp. 357–364; Luther and Brown, Jour. Anim. Sci., 10, 1951, p. 1055; Luther et al., Jour. Anim. Sci., 12, 1953, pp. 923–924; Crane, Jour. Anim. Sci., 12, 1953, p. 912.
53. Atkinson and Hardin, Ind. Bul. 587; Lacy, Wis., Hoard's Dairyman, Feb. 25, 1951; Hughes, Armours Analysis, 1, 1952, No. 3.
54. Terrill et al., Ill. Mimeo. Rpt. A.S. 152; Ferrin, Minn., mimeo. rpt.
55. Hanson, Ferrin, and Aunan, Minn., Jour. Anim. Sci., 12, 1953, p. 919; see also: Christian, Black, and Ensminger, Wash., Jour. Anim. Sci., 11, 1952, p. 738; Self, Grummer, and Casida, Wis., Jour. Anim. Sci., 14, 1955, pp. 573–593.
56. Christian and Nafziger, Wash., Jour. Anim. Sci., 11, 1952, p. 789; Self, Grummer, and Casida, Wis., Jour. Anim. Sci., 12, 1953, p. 954.
57. Mumford, Mo. Res. Bul. 45; McKenzie, Mo. Res. Bul. 118.
58. Mosher, Ill. Bul. 548; Hardin, Weigle, and Wann, Ind. Bul. 565; Nodlund and Pond, Minn. Bul. 379; Wahlstrom, Wilson, and Wright, S.D. Bul. 437.
59. Ferrin and McCarty, Minn. Bul. 213.
60. Wahlstrom, Wilson, and Wright, S.D. Bul. 437.
61. Smith et al., Tenn., information to the author.
62. Hale, Tex. Rpts. 1932, 1933, 1934, 1935.
63. Ransom, U.S.D.A. Leaflet 5; Raffensperger and Connelly, U.S.D.A. Tech. Bul. 44; Spindler, U.S.D.A. Yearbook 1942, pp. 774–780.
64. Wilcox, Carroll, and Hornung, Ill. Bul. 390.
65. Wiley, Ind. Rpts. 1938, 1941.
66. Robison, Ohio Bul. 497.
67. Wiley, Ind. Bul. 318.
68. Wiley, Ind. Bul. 358.
69. Bjorka, U.S.D.A. Tech. Bul. 621.
70. Ashby, Ill. Bul 388.
71. Wiley, Ind. Bul. 237.
72. Summarized by Atkinson and Klein, U.S.D.A. Tech. Bul. 894; see also: Mosher, Ill. Bul. 548; Beneke, Iowa Farm Sci., 5, 1951, No. 10; Nodland and Pond, Minn. Tech. Bul. 379.
73. Wilcox, Carroll, and Hornung, Ill. Bul. 390.
74. Steanson and Wilcox, U.S.D.A. Bul. 1381.
75. Pope and Wingate, Ala. Bul. 240; Grimes, Sewell, and Cottier, Ala Cir. 68; Mosher and Case, Ill. Bul. 444; Buck, Hopkins, and Malone, Iowa Res. Bul. 275; Ky. Rpt. 1933; Hostetler, Nance, and Foster, N.C. Bul. 272; Carroll and Krider, Swine Production, 1950; Smith, Pork Production, 3rd Ed., 1952.
76. Mosher, Ill. Bul. 548.
77. Beneke, Iowa Farm Sci., 5, 1951, No. 10.

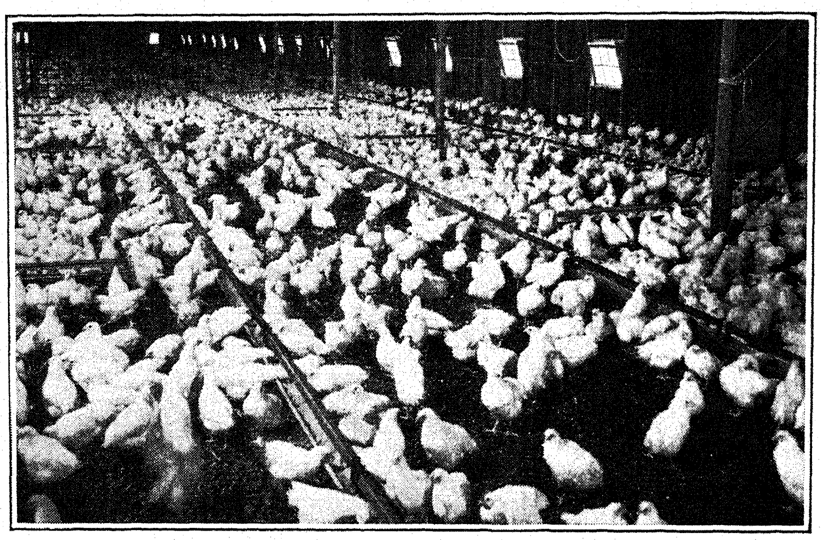
CHAPTER XXXVI

GENERAL PROBLEMS IN POULTRY PRODUCTION

I. Nutrient Requirements of Poultry

1495. Modern poultry production revolutionized by nutrition discoveries.— The discoveries in poultry nutrition during recent years have made possible revolutions in poultry production. Before these discoveries were made, attempts to raise chickens in confinement were often unsuccessful. Also, the egg production of hens was generally unsatisfactory unless fresh green feeds were supplied and unless the hens could get out into sunlight during a considerable part of the year.

Through hundreds of careful experiments most of the nutrient requirements of poultry have now been definitely determined. Their needs are known for protein and amino acids; for minerals, including trace minerals; and for vitamins, including certain unidentified vitamins, or factors. Numerous investigations have also shown that the rate of gain and the feed efficiency of growing poultry can be increased by a suitable antibiotic feed supplement. High-energy rations have been developed, especially for broiler production, which considerably reduce the amount of feed required per pound gain in weight. Much progress has also been made in the control of diseases.



A Large-scale Modern Broiler Plant

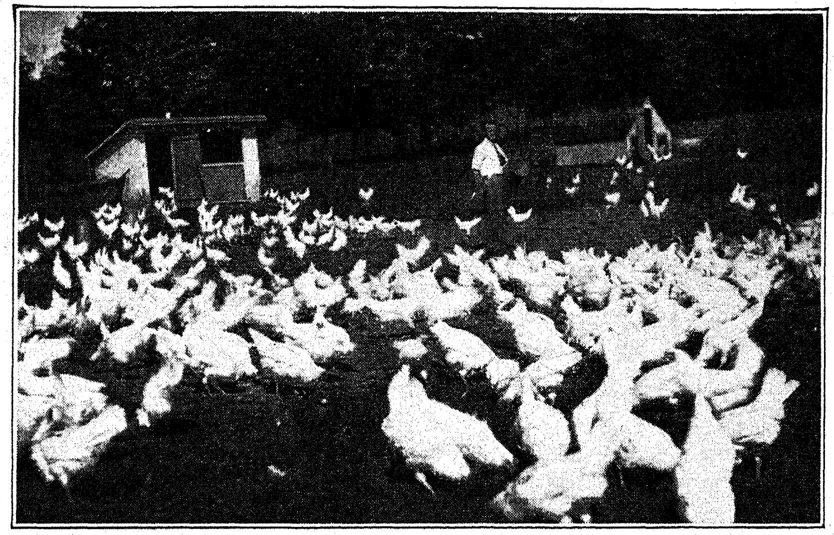
The discoveries in poultry nutrition during recent years have made possible intensive, large-scale poultry production.

As a result of these experiments thrifty chicks can now be raised in confinement and at any time of the year. Also, laying hens can be kept healthy and productive without fresh green feed and without exposure to sunlight. These discoveries have made possible the development of successful intensive meth-

ods of poultry production, in which little or no range or pasture may be used. Sometimes hens are even confined during most of their lives in small individual compartments, or batteries. Although such conditions are far different from those natural for fowls, the hens thrive to a surprising degree, because their nutritive requirements are known and can be fully met.

required per pound of broiler produced, with a range from 2.8 lbs. to 5.4 lbs.[4]

When broilers are fed, with expert management, the best possible high-energy rations, supplemented amply with minerals and vitamins and with an effective antibiotic feed supplement, the gains can now be surprisingly efficient. For example, in a Maryland test recently completed with 7,860 birds of both sexes,



A FARM FLOCK OF CHICKENS

Although modern, scientific methods have made possible intensive, large-scale poultry production, the majority of the chickens in the United States are kept in farm flocks, under more natural conditions. This flock has excellent pasture in summer. (From New York State College of Agriculture, Cornell University.)

the broilers weighed an average of 2.83 lbs. at 8 weeks of age and had required only 2.21 lbs. of feed per pound of weight.[5]

The great changes that have resulted from these recent developments are shown by the following: Only 10 years ago, the average annual egg production per hen in the United States was about 110 eggs.[1] Now, in commercial flocks the annual egg production per 100 hens is estimated at over 18,000 eggs, and above 20,000 eggs in some states.[2]

In cost accounting studies of broiler production only a few years ago, it was found that 4.2 to 4.8 lbs. of feed were required per pound of broiler marketed.[3] In a study for 1951–1952 of the results of 80 New York broiler producers, an average of only 3.7 lbs. of feed were

Large-scale intensive methods of poultry production are of great importance in certain sections of the United States, but the majority of the chickens in the country are kept in farm flocks, under more natural conditions. Here they can get no small part of their feed by foraging during the growing season. Also, they utilize considerable feed that might otherwise be wasted, such as garbage and surplus vegetables.

Of the total number of poultry in

the United States, over 90 per cent are chickens. Because of the great importance of chickens compared with other poultry, the following discussions deal chiefly with them. Brief summaries concerning the production of turkeys, ducks, and geese are given in the next chapter.

1496. Digestion in poultry.—The digestive systems of poultry are much different from those of the larger farm animals.[6] Poultry have no teeth with which to chew their food, the teeth and lips being replaced by the horny beak or bill. Such soft feeds as vegetables, green herbage, or meat can be torn into pieces by the beak, but hard substances like grain are swallowed whole. Since no chewing is done in the mouth, abundant saliva is not needed, and the salivary glands are not well developed.

From the mouth the food is forced down the gullet into the crop, a pouch-like enlargement of the gullet just before it enters the body cavity. The food is stored temporarily in the crop and softened somewhat. From the crop it passes on in small quantities, as it can be accommodated for grinding in the gizzard.

Such hard feeds as whole grain may remain in the crop 12 hours or more. In New York studies 30 to 40 per cent or more of the feed generally remained in the crop 12 hours after it had been eaten.[7] Within 24 hours practically all of it had passed out of the crop.

There is little or no secretion of enzymes in the crop. However, a little digestion may be produced by enzymes contained in the feed, by ptyalin of the saliva, and by bacterial action.

From the crop the food passes through the second part of the gullet into the glandular stomach (called the proventriculus), where the gastric juice is secreted. The food does not remain here any appreciable time, but passes on, mixed with the acid gastric juice, into the gizzard, or muscular stomach (called the ventriculus).

The gizzard is a powerful, muscular grinding apparatus, with a tough horny lining. In it the food is finely ground with the aid of grit or small pebbles. Though grit is not necessary for the grinding action of the gizzard, it enables chickens to make more efficient use of whole grains and coarse, fibrous feeds. (**1514**)

From the gizzard the partly-digested food passes into the small intestine, in which the digestive processes are similar to those in other farm animals. Most of the gastric digestion takes place in the first part of the small intestine. Farther along, the food is acted on by the bile, the pancreatic juice, and the intestinal juice.

The large intestine in poultry has but small capacity and is of minor importance in digestion. It consists of a short rectum and two ceca, or blind guts, at the juncture of the small intestine and the rectum.

In poultry the urine and the feces are not voided separately, but both are excreted through a common chamber, called the cloaca. Most of the water in the urine is reabsorbed in the cloaca, and the urine is voided as a whitish paste with the feces. The nitrogenous waste is excreted chiefly in the form of uric acid and urates, instead of urea, as with mammals.

1497. Digestibility of feeds by poultry.—For feeds low in fiber, such as corn, wheat, or the grain sorghums, there is no great difference in the digestibility by poultry and by cattle or sheep. On the other hand, the digestibility by poultry of feeds high in fiber is low. This is because they have little ability to digest fiber, except that in some green forages and in roots.

Since the urine is not voided separately by poultry, digestion trials cannot be conducted with them by the same methods that are used with the larger farm animals. To determine the approximate digestibility of feeds by poultry, methods have sometimes been used to separate the feces from the urine, or to estimate the amount of nitrogen in the urine.

1498. Feeding standards; nutrient allowances.—Feeding standards based upon digestible nutrients are not commonly used in poultry feeding. This is because there is very little information concerning the actual amounts of digest-

ible nutrients furnished to poultry by various feeds.

The standards for poultry are generally stated in terms of total protein and of other required nutrients. Also, because of the small size of poultry, the standards are usually stated in terms of the amounts of the various nutrients required per pound of feed, instead of the allowances per head daily. For these reasons, feeding standards for poultry are not included in the feeding standards presented in Appendix Table III.

The standards used generally in this country are those prepared by a special committee of the National Research Council in a report entitled, *"Recommended Nutrient Allowances for Poultry."* [8] These standards for chickens, which have been recently revised, are given in detail in the following table. The standards for turkeys are given in Chapter XXXVII.

Nutrient requirements of chickens [1]

	Starting chickens 0–8 weeks	Growing chickens 8–18 weeks	Laying hens	Breeding hens
Total protein, per cent	20	16	15	15
Vitamins				
Vitamin A activity (U.S.P. Units) [2]	1200	1200	2000	2000
Vitamin D_3 (International Chick Units)	90	90	225	225
Thiamine, mg.	0.8	?	?	?
Riboflavin, mg.	1.3	0.8	1.0	1.7
Pantothenic acid, mg.	4.2	4.2	2.1	4.2
Niacin, mg.	12	?	?	?
Pyridoxine, mg.	1.3	?	1.3	1.3
Biotin, mg.	0.04	?	?	?
Choline, mg. [3]	600	?	?	?
Folacin, mg.	0.25	?	0.11	0.16
Minerals				
Calcium, per cent	1.0	1.0	2.25 [4]	2.25 [4]
Phosphorus, per cent [5]	0.6	0.6	0.6	0.6
Salt, per cent [6]	0.25–0.50	0.25–0.50	0.5	0.5
Potassium, per cent	0.2	0.16	?	?
Manganese, mg.	25	?	?	15
Iodine, mg.	0.5	0.2	0.2	0.5
Magnesium, mg.	220	?	?	?

1 These figures are estimates of requirements and include no margins of safety.
2 May be vitamin A or carotene.
3 May be partially replaced by betaine.
4 This amount of calcium need not be incorporated in the mixed feed, inasmuch as calcium supplements fed free-choice are considered as part of the ration.
5 At least 0.45 per cent of the total feed of starting chickens should be inorganic phosphorus. All of the phosphorus of non-plant feed ingredients is considered to be inorganic. Approximately 30 per cent of the phosphorus of plant products is non-phytin phosphorus and may be considered as part of the inorganic phosphorus required. A portion of the phosphorus requirement of growing chickens and laying and breeding hens must also be supplied in inorganic form. For birds in these categories the requirement for inorganic phosphorus is lower and not so well defined as for starting chickens.
6 This represents salt or sodium chloride added as such or in marine or fermentation products of high sodium chloride content. In the table published by the committee, the added salt requirement is given as 0.5 per cent for all classes of chickens. Because of the results secured in recent experiments with chicks, the author has given in this table a range of from 0.25 to 0.50 per cent of added salt in rations for starting chicks and for growing chickens. (1510)

It is important to note that these revised standards are estimates of minimum requirements and do not include any margins of safety, such as there are in the feeding standards for other animals, given in Appendix Table III. To provide for variations in the composition of feeds and differences in the requirements of individual birds, the amounts

recommended of certain nutrients in the earlier standards were considerably above the estimated minimum needs.

For example, the following margins of safety were provided in the earlier standards: Vitamin A for hens, over 60 per cent; vitamin D, 50 per cent; B-complex vitamins, 20 per cent.

In using the preceding table to formulate practical rations, it is therefore important to see that the amounts of nutrients provided are sufficiently above these minimum requirements to be safe under all conditions.

The requirements of chickens for the various nutrients are considered in detail in the articles which follow. Information concerning the desirable proportions of various types of ingredients in poultry rations is given in the example rations presented in Appendix Table VII. These rations may readily be modified to meet the conditions in various regions.

1499. Percentages of protein.—The protein requirements of poultry are commonly stated in terms of the percentages of total protein (not digestible protein) which are needed in rations for good results when the protein is of satisfactory quality.

In the standards of the committee of the National Research Council, which have been given in the preceding table, not less than 20 per cent total protein is advised in a ration for chicks up to 8 weeks of age, and 16 per cent from 8 to 18 weeks of age. For laying hens, including breeders, the minimum recommended is 15 per cent.

Chickens fed high-energy rations, which are discussed later, need a slightly higher percentage of protein than do those fed rations containing more fiber. **(1533)** This is because a little less weight of feed is usually consumed on a high-energy ration. For the birds to secure the proper amount of protein per day, the percentage of protein must be slightly higher.

Formula feed manufacturers consequently give attention to the proportion, or ratio, between the Calories of net energy, or productive energy, and the percentage of protein in high-energy mashes.[9] **(1531)**

Numerous experiments have been conducted to compare various levels of protein in rations for growing chickens.[10] These experiments have shown that good gains are made on rations containing the percentages of protein stated in the table. However, the rate of gain may be slightly more rapid, especially for chicks of the heavier breeds, if the ration has at least 21 per cent of protein for the first 6 to 8 weeks, and then at least 17 per cent.

In a recent New York experiment with Single Comb White Leghorn pullet layers fed a high-energy ration, 15 per cent of total protein was sufficient for a strain of birds that reached a mature average weight of 5 lbs.[11] Pullets of a smaller strain, which averaged about 4 lbs. in weight at maturity, needed between 15 and 16.5 per cent of protein in the ration.

When hens are fed mash and scratch grain and consume about equal weights of each, the mash should have not less than 20 to 21 per cent of protein. This will provide about 15 per cent of protein in the entire ration.

Poultry on protein-rich pasture, such as alfalfa or Ladino clover, need considerably less protein in the concentrates than do hens not on pasture. In experiments in Scotland, rations having only 11 to 12 per cent protein were adequate for hens on good pasture.[12]

1500. Quality of protein.—In poultry rations it is fully as important to have protein of good quality as it is to have a sufficient amount of protein. **(107–129)** Rations in which the protein comes entirely from grain and grain by-products produce poor results, because of poor quality of protein, even if there are ample supplies of minerals and vitamins.

Fish meal, meat scrap, tankage, and dairy by-products have a high value as protein supplements in poultry rations. **(114, 121, 845, 905, 920)**

Fish meal and also skimmilk and other dairy by-products are very efficient in correcting the deficiencies in the proteins of the grains and the grain by-products. Meat scrap and tankage are

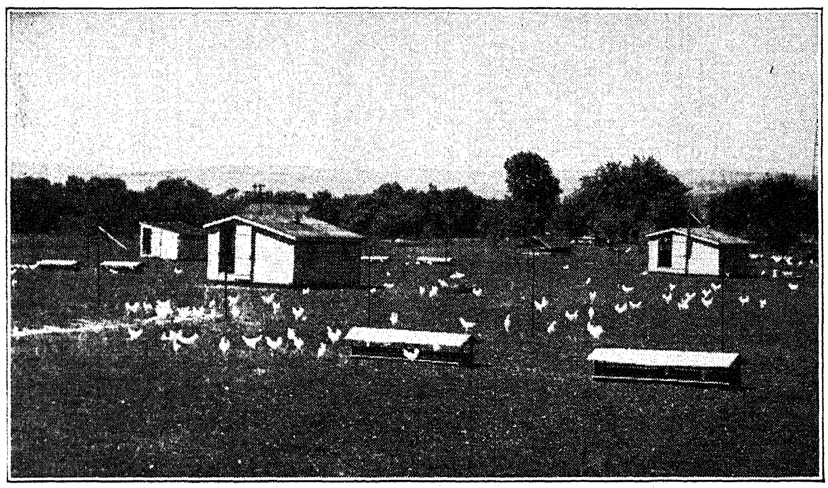
also effective protein supplements for the grains, except that in a ration consisting almost entirely of corn and one of these supplements there may be a slight deficiency of tryptophan, as is pointed out later. (**1503**)

Excellent results are secured when only these feeds of animal origin are used to balance grains and grain by-products in poultry rations, with whatever mineral or vitamin supplements are needed in addition. However, it is generally cheaper and more economical to use much smaller amounts of these animal-protein supplements than would be required to balance a ration fully, and to supply a large part of the needed protein by protein supplements of plant origin.

Part of the high value for poultry of the protein supplements of animal origin is due to their richness in calcium and phosphorus and also in their content of vitamins. Therefore, when plant-protein supplements are used as the only or the chief protein supplements in poultry rations, care must be taken to add whatever mineral and vitamin supplements may be needed.

The value and use for poultry of the many different protein supplements are discussed in detail in the chapters of Part II. It is there emphasized that soybean oil meal which has been properly cooked in the manufacturing process ranks next to the protein supplements of animal origin for poultry. (**806**)

If the ration is properly supplemented with calcium, phosphorus, and riboflavin, soybean oil meal gives excellent results when it replaces the major part of the animal-protein supplements needed to balance rations for chicks, growing pullets, or laying hens.



Good Pasture Helps Meet the Nutrient Requirements

Poultry on good pasture, such as this, have an abundance of most vitamins. Also, the pasture forage helps to meet the protein and mineral requirements. (From New York State College of Agriculture, Cornell University.)

If care is taken to supply proper amounts of minerals and vitamins, reasonably good egg production and growth of chicks can be obtained when soybean oil meal replaces all of the animal-protein supplements. However, for the best results, a certain minimum amount of feeds of animal origin should be included in the ration. In the case of poultry that are confined, there is a greater benefit from including in the ration such supplements as meat scrap, fish meal, or dairy byproducts, than there is for poultry which are on good pasture. This is due both to the quality of protein in good pasture

forage and to the worms and insects they secure on pasture.

Peanut oil meal probably ranks next to soybean oil meal as a substitute for animal-protein supplements. (**841**) Corn gluten meal is a satisfactory substitute for one-half of the meat scrap in poultry rations, but should not be used as the chief protein supplement, as the protein is not of high quality. (**716**) Similarly, corn distillers dried grains should be used only in combination with supplements which provide protein of good quality. (**954**)

1501. Minimum proportions of animal-protein supplements.—Numerous experiments have been conducted to determine the minimum proportions of animal-protein supplements that are needed in poultry rations for optimum results.[13]

The example rations in Appendix Table VII indicate the percentages of feeds of animal origin commonly recommended in poultry mashes. For the best results, starting mashes for chicks should generally have at least 5 to 7 per cent of animal-protein supplements. Complete mashes for growing chickens and laying hens should contain not less than 3 to 4 per cent of animal-protein supplements; mashes to be fed with grain to growing chickens and laying hens, 5 to 7 per cent; and breeding mashes to be fed with grain to hens producing hatching eggs, 7 to 10 per cent.[14]

It should be remembered that these are the minimum percentages of animal-protein supplements recommended for optimum results. When there is a plentiful supply of feeds of animal origin and the prices are not unduly high, somewhat larger proportions of these feeds are desirable in poultry rations.

1502. Amino acid requirements.—The approximate percentage of each of the essential amino acids required in rations for chicks has been determined by adding definite amounts of the particular pure amino acid to a diet low in this amino acid. Similar data have been secured for a few amino acids in experiments with laying hens. The requirements for chicks and for layers are shown in the following table. The information concerning the amino acid requirements of turkey poults is summarized in Chapter XXXVII.

The data in this table are mainly the requirements stated in the report of the committee of the National Research

Essential amino acid requirements	Starting chicks Per cent of ration	Laying hens Per cent of ration
Arginine	1.7	...
Glycine [1]	1.0	...
Histidine	0.15	...
Isoleucine	0.6	0.5
Leucine	1.4	1.0
Lysine	1.0	0.5
Methionine	0.7	0.53
or		
Methionine,[2] plus	0.33	0.28
Cystine	0.35	0.25
Phenylalanine	1.6	...
or		
Phenylalanine,[3] plus	0.9	...
Tyrosine	0.7	...
Threonine	0.6	...
Tryptophan	0.15	0.15
Valine	0.8	..

1 The chick can synthesize glycine, but not at a rate sufficient for maximum growth. Glycine can be replaced by serine and partially by arginine.

2 Cystine will replace part of the methionine, as long as the ration contains not less than the percentages of methionine shown.

3 Tyrosine will replace part of the phenylalanine, as long as the ration contains not less than 0.9 per cent phenylalanine.

Council, which has been mentioned previously.[8] Where more recent experiments have provided further information, changes have been made by the author in the requirements for certain amino acids.[15]

It should be borne in mind that this table shows the percentages of the amino acids needed in the entire ration. When chickens are fed both a mash and grain separately, the mash must supply sufficient of the essential amino acids to correct the deficiencies in the protein of the grain, and provide the proper amounts in the entire ration.

The numerous investigations on the amino acid requirements of chicks have shown that the only amino acids which may be deficient in practical, well-balanced rations are methionine, tryptophan and lysine. Since hens apparently need smaller percentages of the essential amino acids than do chicks, it is not likely that there will be a deficiency, even of these amino acids, in rations that are otherwise satisfactory for layers.[16]

1503. Correcting amino acid deficiencies.—Appendix Tables VIIIa and VIIIb give the approximate percentages in important feeds of the essential amino acids, and also of cystine, which can partially replace methionine. Table VIIIa states the percentages of the amino acids in the various feeds, while Table VIIIb states the percentages of the different amino acids there are *in the protein* of the particular feed.

Since feeds differ very widely in protein content, the latter table best shows whether the protein of a given feed is a good source of any amino acid, or whether it is low in it.

By the use of Table VIIIa, a formula feed manufacturer can determine whether or not a particular mash formula will provide sufficient percentages of the essential amino acids. It must be remembered that data concerning the minimum requirements of the different amino acids are still limited, and that various lots of the same kind of feed apparently differ considerably in content of the important amino acids.

If a certain mash formula seems to be deficient in lysine, tryptophan, or methionine, then the formula should be modified to correct the lack. This can be done by including in the mash a sufficient amount of a feed that is rich in the particular amino acid which is in short supply.

As has been pointed out previously, methionine is the only pure essential amino acid which is at present available at a price that makes its use feasible in practical rations. In addition to pure methionine, certain related compounds, called methionine analogues, are available commercially. These can be used instead of methionine, because they can be converted into methionine within the body.

The following examples show how an amino deficiency can be corrected by the use of a feed rich in the particular amino acid. The protein in all of the cereal grains is low in lysine. Corn, milo, and barley are especially deficient. To correct this lack, a protein supplement rich in lysine must be included in the ration.

Peanut oil meal or degossypolized cottonseed meal does not provide sufficient lysine to correct the deficiency, if either of these feeds is used as the only or the chief protein supplement to corn or other grain.[17] The lack can be remedied by using soybean oil meal, meat scrap, tankage, fish meal, dried skimmilk, or brewers' dried yeast to furnish enough of the protein in the ration.

A combination of corn supplemented entirely by meat scrap or tankage may be a little deficient in tryptophan.[18] Soybean oil meal, fish meal, degossypolized cottonseed meal, dried skimmilk, sesame oil meal, and distillers dried solubles all have more than twice as much tryptophan per pound of protein as does meat scrap or tankage. (Appendix Table VIIIb.) Therefore, the tryptophan lack can be corrected by including sufficient of one or more of these feeds in the mash. Alfalfa meal and wheat standard middlings also have a good content of tryptophan. However, because of their fiber content and bulk, only a small percentage of these feeds can be included in a chick mash.

There is commonly no lack of leucine in poultry rations. However, it has recently been reported that when all the grain in a ration for laying hens is wheat or barley, there may be a lack of this amino acid.[19] Corn and milo have more leucine than do wheat and barley. Corn gluten meal, sorghum gluten meal, fish meal, meat scrap, and tankage are rich in it, and cottonseed meal, distillers solubles, and dried skimmilk are good sources.

The manner in which the deficiencies in the protein in each of two feeds can be corrected when they are combined properly, is shown by the data in Appendix Table VIIIb for corn gluten meal and for soybean oil meal. Corn gluten meal protein is low in lysine, but it has considerably more methionine than does soybean oil meal. On the other hand, soybean oil meal protein has a good content of lysine and tryptophan, but is rather low in methionine. When these two feeds are combined, the amino acid deficiencies of each are corrected.

1504. Methionine supplementation.—Rations for chicks in which soybean oil meal, peanut oil meal, or degossypolized cottonseed meal is used as the only or the chief protein supplement may not supply quite enough methionine for the most efficient gains. This is of particular importance in large-scale broiler production.

Only a few feeds supply more methionine than do these protein supplements. Fish meal commonly has more than twice as much, and sesame oil meal and well-hulled sunflower-seed oil meal are good sources of methionine. There is as yet much less information concerning the content in feeds of cystine, which can partially replace methionine.

Because of the few natural feeds that have a liberal amount of methionine, many experiments have been conducted recently, usually with broilers, to determine the effects of adding pure methionine to the ration. While the results of the trials have differed decidedly, in the majority of the tests conducted by the experiment stations, the amount of feed required per pound of gain has been appreciably reduced by the methionine supplement.[20] In many trials this has occurred even when the rate of gain has not been increased.

Whether there will be sufficient improvement in feed efficiency to cover the cost of the added methionine will depend chiefly on the amount in the ration of fish meal or other good sources of the amino acid.

Usually only 0.5 to 1.0 lb. of methionine is added per ton of mash. A methionine analogue should be used as directed by the manufacturer. More than the recommended amount of methionine supplement may be definitely detrimental.

1505. Fat.—Experiments in which chicks have been fed rations in which all the fat has been removed have shown that they may require very small traces of the highly unsaturated fatty acids discussed in Chapter V.[21] (133) On the other hand, if hens need these fatty acids, they can apparently synthesize the necessary amounts in their bodies.[22]

Any practical poultry ration furnishes sufficient fat and enough of these unsaturated fatty acids for good results. Therefore, in feeding standards for poultry, it is not necessary to state any minimum requirement of fat.

In several trials the effects have been studied of feeding rations in which most of the fat has been extracted experimentally. Chicks made normal growth in Indiana experiments on a ration containing only 1 per cent fat, and in New Jersey studies the growth was nearly as rapid on a ration having only 0.1 per cent fat as on a normal ration.[23] In a Louisiana trial the growth of chicks was somewhat slower on a ration containing practically no fat, but the effect was overcome during later growth.[24] On a low-fat ration the body fat is harder than normal, since practically none of it comes from the feeds and nearly all is made from the carbohydrates. (276)

In New Jersey experiments with laying hens, reducing the fat content of the ration to 1.6 per cent had no unfavorable effect on egg production, fertility, hatchability of eggs, or mortality.[25] However, when a ration was fed which had prac-

tically no fat (containing only 0.07 per cent fat) the utilization of carotene was greatly decreased. The absorption of vitamin A was not reduced, but much less of the vitamin was stored in the liver than on a normal ration. These effects are probably due to the fact that carotene and vitamin A are both soluble in fat.

In an Arizona experiment, egg production was nearly normal on a ration having only 0.8 per cent fat.[26] However, in a Louisiana trial a ration having practically no fat decreased egg production and lowered hatchability.[27]

1506. Addition of fat to rations.—The addition of by-product animal fat to livestock rations has been previously discussed in general. (134) Because of the surplus of such greases and tallows during recent years, the prices of these fats have fallen to levels that have made their addition to formula feeds practicable. Several experiments have therefore been conducted to find the effects of adding such fats to poultry mashes.

The fat addition increases the energy value of a ration, and consequently the birds generally eat a somewhat smaller weight of feed. It is therefore important to have in the mash enough protein, vitamins, and minerals to offset this lower feed consumption. Also, a fat should be used to which an effective antioxidant has been added, to prevent rancidity and vitamin destruction. Hydrogenated fat with a very high melting point is not utilized well by poultry.

In the experiments with broilers and other chicks, adding up to 8 or perhaps 10 per cent of by-product grease or tallow to a good mash has increased the feed efficiency in most cases.[28] Adding a greater percentage may be less desirable. Also, mash having as much as 12 per cent of added fat may tend to cake in cold weather. The effect of the fat addition on rate of gain has differed, and in some cases the gain has not been increased.

In these experiments the added fat has generally had a somewhat higher value per pound than would be expected from its energy value. This is commonly estimated at 2.25 times the energy value of a pound of starch.

The addition of fat to the ration during the finishing period for broilers may be especially advantageous, because it tends to increase the fleshing and the fat content of the meat.

In a New York trial with laying hens, the addition of 2.5 or 5 per cent tallow to a high-energy ration did not significantly increase egg production in fall, spring, or summer.[29] On the other hand, the fat addition consistently increased egg yield in winter.

The addition of fat appreciably decreased the weight of feed required per dozen eggs, the decrease being approximately 2 per cent for each per cent of added fat. The added fat had a higher value than the usual estimated net-energy value.

1507. Minerals.—The requirements of poultry for calcium and phosphorus are greater than those of the larger farm animals. Special consideration must therefore be given to the amounts of these minerals in making up poultry rations. Salt should be provided for poultry, but the requirement is relatively low.

While it is not generally necessary to give any consideration to manganese in feeding other livestock, a very small amount of manganese supplement must often be added to poultry rations to prevent serious nutritive deficiencies. In iodine-deficient areas, it is advisable to use iodized salt for poultry, instead of ordinary salt, or to include in the ration some feed that serves as an iodine supplement. The requirements for these and other minerals and also the use of grit and of charcoal in poultry rations are discussed in the following articles.

1508. Calcium.—Poultry need a much higher content of calcium in their rations than do other farm animals.[13] Laying birds need especially large amounts, because egg shells are composed almost entirely of calcium carbonate. The calcium requirement for chicks and growing poultry is also high because of their rapid growth.

It will be noted that in the nutrient requirements stated by the committee of

the National Research Council, 2.25 per cent of calcium is recommended in rations for laying hens and 1.0 per cent in rations for chicks. (**1498**) Rations for growing turkeys should have about 2.0 per cent of calcium. (**1586**) These recommendations are based on numerous experiments that have been conducted to find the optimum calcium content of poultry rations.

For laying hens, a common plan is to include in the mash only enough calcium supplement to provide part of the requirement, and to let the hens have access at all times to oyster shell or limestone grit fed separately. When both mash and grain are fed, from 1.0 to 2.5 per cent of ground limestone or other calcium supplement is generally included in the mash. Even 2.5 per cent will supply less than one-half of the requirement, as high-calcium limestone contains approximately 38 per cent of calcium.

For poultry there should be a suitable proportion, or ratio, between the amounts of calcium and of phosphorus in the ration. This proportion is called the calcium-phosphorus ratio. (**152**) For chicks, it seems most desirable to have about 1.5 times as much calcium in the ration as there is of phosphorus.[30] The calcium-phosphorus ratio is then 1.5 : 1. However rations ranging from 1.0 : 1 to 2.5 : 1 have been used in chick rations without decidedly detrimental results.

Laying hens require a much larger proportion of calcium, because of the great amount in the egg shells. It will be noted that in the table of "Nutrient allowances for chickens," for laying hens more than 3 times as much calcium is advised as of phosphorus. (**1498**)

The great need for calcium in egg production is well shown by a study in Scotland.[31] It was found that at the outset of laying, a pullet's body contains 25 to 30 grams of calcium. Each egg, including the shell, has about 2 grams. Thus, in producing 200 eggs, the pullet must have available more than 13 times as much calcium as there was in her body when she started laying.

A decided deficiency of calcium in poultry rations produces serious results. The egg production of hens is greatly reduced, and many of the eggs have weak shells. For example, in an Ohio experiment the percentage egg production of pullets fell from a daily average of 45 per cent to 20 per cent in 2 weeks when they were fed no calcium supplement.[32] During the entire 46 weeks of the trial, these pullets laid only one-half as many eggs as did pullets receiving ample calcium. Also, 76 per cent of their eggs had weak shells.

It was found in South Carolina investigations that even when the ration had an ample amount of calcium, hens steadily lost calcium from their bodies during the first few weeks after they started to lay.[33] As much as 25 per cent of the entire amount of calcium in their bodies may thus be lost in 6 weeks. Later the hens are able to utilize the calcium in their feed more efficiently, and to regain the calcium store in their bodies without slackening egg production.

An excessive amount of a calcium supplement should not be included in a poultry mash. A considerable excess of calcium interferes with the utilization of manganese, and it may reduce egg production and lower the hatchability of the eggs.[34] When the usual percentage of calcium supplements is included in the mash and hens are provided with oyster shell or limestone grit in addition, there is no danger of their eating an excessive amount of it.

The calcium supplements used most commonly for poultry are high-calcium limestone and oyster or clam shell. Oyster shell is preferred by many poultrymen, but experiments have shown that high-calcium limestone is equally satisfactory, except perhaps in regions where there is a deficiency of iodine.[35] In such areas the iodine furnished by oyster shell may be beneficial, but iodine can also be supplied readily by using iodized salt instead of common salt. Dolomitic limestone, which is high in magnesium carbonate, is not satisfactory for poultry. Other suitable calcium supplements are listed in Chapter VI. (**157**) The calcium in bone meal, defluorinated phosphate, or gypsum (calcium sulfate) can be used

efficiently for growth, but is definitely inferior to calcium carbonate for egg production.

Interesting experiments have been conducted recently with radioactive calcium and phosphorus to study the assimilation of these minerals and their transference to the egg and from the egg to the chick.[36]

1509. Phosphorus.—It is shown in the table of *"Nutrient allowances of chickens"* earlier in this chapter that rations containing 0.6 per cent total phosphorus are advised for chicks, growing chickens, and hens. (**1498**) In recent experiments somewhat less phosphorus has been satisfactory for growing chickens and for hens, when there was a proper calcium-phosphorus ratio and an ample amount of vitamin D.[37]

For chicks, the greater part of the phosphorus should be in inorganic form, because they do not well assimilate phosphorus in the form of phytin. (**151**) As stated in the footnote following the table, in a ration for chicks there should be at least 0.45 per cent of inorganic phosphorus.

As much as three-fourths of the phosphorus in the grains and the by-products of grains and other seeds may be phytin phosphorus. It is therefore important that part of the phosphorus be supplied in readily available forms.

Older chickens make somewhat better use of phytin phosphorus than do chicks, but a part of the phosphorus in rations for growing chickens and for hens should be in inorganic form.[38] However, the percentage of inorganic phosphorus they need has not been definitely determined.

As stated in Chapter VI, there is less difference in assimilation of phytin phosphorus when there is an abundant supply of vitamin D in the ration. Also, the assimilation of phytin phosphorus may be improved when the ration contains natural, unheated roughages, such as green forage or sun-cured alfalfa meal. Such roughage contains an enzyme which can split phosphorus off from the phytin.

The phosphorus in meat scrap, tankage, fish meal, and dairy by-products is largely in inorganic form and is readily available to poultry.

When meat scrap, tankage, fish meal, and dairy by-products are used as the chief protein supplements in poultry rations, there will usually be sufficient phosphorus, without the addition of any special phosphorus supplement. On the other hand, if soybean oil meal or other protein supplements of plant origin furnish most of the protein, it will be necessary to add phosphorus, as well as calcium.

Some years ago bone meal was often added to chick mashes in which meat scrap, tankage, or fish meal was the chief or only protein supplement. Experiments proved, however, that the addition of a phosphorus supplement to such a ration was decidedly detrimental. Because of the excessive amounts of phosphorus and calcium, the manganese in the ration was rendered unavailable, and perosis, or slipped tendon, was produced.

Information is given in Chapter VI concerning the value of various phosphorus supplements, and about the injurious effects produced by rock phosphate or other phosphates that contain a dangerous amount of fluorine. (**158–169**)

Properly made bone meal is an excellent phosphorus supplement for poultry. In experiments to compare various sources of phosphorus, defluorinated phosphates and dicalcium phosphate have also ranked high in availability.[39] When used as the only phosphorus supplement, ground rock phosphate or colloidal phosphate (soft phosphate with colloidal clay) has been poorly utilized in some experiments. Colloidal phosphate may give better results when used in combination with bone meal.

1510. Salt.—Salt is needed by poultry, but the requirement is relatively small. In the report of the committee of the National Research Council on the nutrient requirements of chickens, the addition of 0.5 per cent of salt to rations for chickens was recommended. (**1498**)

However, New York experiments with chicks have shown that the addition of only 0.25 per cent salt to an or-

dinary ration for chicks was sufficient.[40] Including 0.5 per cent of salt tended to make the droppings moist. A range of 0.25 to 0.5 per cent in added salt is therefore given in the table presented earlier in this chapter.

If hens or growing chickens are fed scratch grain and mash separately, the mash should contain about 1 per cent of salt. When meat scrap, tankage, or fish meal is used as the chief protein supplement, only 0.5 per cent of salt need be added to the mash, because these feeds contain more salt than do the grains or the by-products of grains and other seeds.

Too great an amount of salt is injurious to poultry. In a Pennsylvania trial adding 5 per cent of salt to a ration for chicks caused high mortality, and in a North Dakota test a ration having 4 per cent was detrimental to turkey poults.[41] In this test rations with 6 per cent or more of salt caused heavy death loss.

1511. Manganese; prevention of perosis, or slipped tendon.—It has been shown in Chapter VI that poultry have special needs for manganese. (**180**) A deficiency of manganese is the chief cause of perosis, or slipped tendon, in chicks, in which the legs are deformed by the slipping of the Achilles' tendon from the proper position. Usually only one leg is affected, but sometimes both are deformed. The deficiency also causes a shortening and thickening of the long bones of the legs and wings.

Perosis may also be caused by a deficiency in experimental rations of certain B-complex vitamins—choline, biotin, or folic acid.

Manganese is needed for egg production and good hatchability. Experiments have shown that if hens are fed a ration deficient in manganese, egg production is decreased, the strength of the egg shells is lowered, and the hatchability of the eggs is greatly reduced.[13] Many chicks that fail to hatch are characteristically deformed, with parrot-like beaks and short legs and wings.

Deficiencies of manganese are most apt to occur in poultry kept in strict confinement, with no access to pasture or sunlight. Plymouth Rocks and other heavy breeds apparently require more manganese than do White Leghorns.

Only mere traces of manganese are needed in rations to prevent any deficiencies. It will be noted in the table of "*Nutrient requirements of chickens,*" on a previous page of this chapter, that only 25 milligrams of manganese are needed per pound of feed in starting rations for chicks and 15 milligrams per pound of feed in rations for breeding hens. (**1498**) These allowances are equivalent to 55 parts and 33 parts of manganese per million parts of feed.

It has been pointed out previously that when a ration is high in calcium and phosphorus, the supply of manganese must be greater than otherwise, because the assimilation of manganese is reduced. This is apparently because of the formation of compounds in which the manganese is unavailable. It is believed that these recommended allowances are ample, even when there is a liberal supply of calcium and phosphorus in the ration.

A deficiency of manganese is not apt to occur when there is considerable wheat bran or wheat middlings in the ration, for they have a good content of the mineral. Rice bran is very high in manganese, and fish meal, soybean oil meal, and alfalfa meal have much more than do corn, barley and the grain sorghums.

To guard against a possible deficiency of manganese, one-quarter pound of manganese sulfate is now generally added to each ton of formula mash to be fed without additional grain, and one-half pound per ton to mashes to be fed with grain.

1512. Iodine.—In areas deficient in iodine, goiter (enlarged thyroid gland) may occur in poultry, but egg production and health of the fowls are not generally affected appreciably. (**170**) However, in such areas, it is wise to use iodized salt instead of common salt for poultry, or to include in the ration a feed such as fish meal, that serves as an iodine supplement.

It will be noted that in the table of "*Nutrient requirements of chickens*" an

allowance of 0.5 milligram of iodine per pound of feed is recommended. (1498) This is only 1.1 parts of iodine per million parts of feed. In recent experiments by the Indiana Station a very much smaller trace of iodine (only 0.07 part per million parts of feed) produced normal growth of chicks.[42]

Several experiments have been conducted in this country and in Europe to find whether there was any advantage in adding iodine to ordinary poultry rations in other regions than those known to be deficient in iodine. Ewing concludes from a review of such experiments that in the experiments conducted in this country there has been no evidence of a benefit to poultry from such an addition of iodine, and that in European experiments the data have been conflicting.[43] Feeding a ration high in iodine definitely increases the iodine content of eggs.

1513. Other minerals.—The requirements of chicks for potassium and magnesium are stated in the table of *"Nutrient requirements of chickens."* (1498) However, there is no lack of either of these minerals in ordinary poultry rations. Neither does there seem to be a deficiency of cobalt, iron, copper, or sulfur in practical poultry rations.

It is pointed out later that recent experiments have shown that one of the unidentified factors required by chicks is an unrevealed trace mineral or a combination of such minerals. (1528)

1514. Grit.—Grit aids in the grinding of whole grain or other coarse feed in the gizzard. Also, crushed oyster shell or limestone grit furnishes calcium as it dissolves. Some limestone is too soft to be an effective grinding agent. Insoluble grit, such as granite or quartz grit, serves as grinding material, but not as a calcium supplement.

Experiments have shown that grit should be supplied laying hens, and that it is best to furnish hard grit in addition to limestone grit or oyster shell. In Ohio experiments, supplying layers with hard grit in addition to limestone grit or oyster shell increased the egg production 9.6 per cent and reduced the feed requirement per dozen eggs 7.1 per cent.[44] Because of the small amount of hard grit consumed, the addition resulted in a material saving in the cost of egg production. If an all-mash ration is fed layers, grit may not be necessary. Screened gravel of suitable size is a satisfactory form of grit.

Experiments have shown that there is little or no advantage in supplying grit for chicks up to 4 to 8 weeks of age when they are fed the usual type of ground mash.[45] After that, there was some benefit from supplying grit, especially if the mash was coarsely ground, and it was desirable to supply hard grit in addition to limestone grit or oyster shell.

1515. Charcoal.—Years ago it was a common practice to add charcoal to poultry rations as an absorbent of gases and a corrective of diarrhea. Experiments have shown, however, that there is no advantage from adding it to ordinary rations.[13]

In fact, because of the absorptive and adsorptive power of charcoal, adding it to a ration may produce a vitamin deficiency, unless the ration contains a very abundant supply of vitamins. (182) Also, because of this effect, charcoal tends to absorb xanthophyll and other yellow pigments in the feed, and to produce pale shanks and skin.

1516. Vitamins.—Except for poultry which are on good pasture or which are fed plenty of fresh green forage, it it necessary to give much more attention to their vitamin requirements than in feeding cattle, sheep, or horses. This is due to four factors.

First, rations for poultry consist chiefly of grains and other concentrates, with very little roughage. Second, there is but little synthesis of B-complex vitamins in the digestive tract of poultry. Third, the vitamin requirements of poultry, especially for vitamin A, vitamin D, and riboflavin, are much greater, per pound of live weight, than those of other farm animals. Fourth, in addition to the vitamins which have been identified, poultry require certain unidentified vitamins or factors.

The requirements of poultry for the

various vitamins and for the unidentified vitamins or factors are discussed in the articles which follow.

1517. Vitamin A and carotene.—A liberal supply of vitamin A or carotene is needed for normal growth, also for health, even of mature fowls, and for satisfactory egg production. Poultry are about equal to rats in the efficiency with which they utilize carotene as a source of vitamin A. One U.S.P. Unit (United States Pharmacopoeia Unit) supplied in the form of carotene therefore has approximately the same value as an I.U. supplied in the form of vitamin A. (**194**) As has been pointed out previously, other farm animals use carotene less efficiently than they do vitamin A.

A part of the vitamin A value in poultry rations is often supplied by fish liver oils or other animal sources that furnish true vitamin A. For this reason and also because of the approximately equal value of an International Unit in the form of vitamin A and of carotene, the requirements of poultry are generally stated in terms of International Units of vitamin A value. On the other hand, the requirements of other livestock are commonly given in milligrams of carotene, since carotene usually furnishes all the vitamin A value in their rations.

It will be noted in the table of "*Nutrient requirements of chickens*" that the committee of the National Research Council gives the vitamin A requirement of chicks and growing chickens as 1,200 U.S.P. Units per pound of feed. (**1498**) The requirement of laying hens and of hens producing hatching eggs is given as 2,000 U.S.P. Units per pound of feed.

It is important to bear in mind that in this revised statement of requirements by the committee no margins of safety are included, to cover losses of vitamin value during feed processing and storage and to cover variations in vitamin A content of various lots of the same kind of feed. In making up poultry mashes, it is necessary to provide a considerably higher initial vitamin A content, to make up for the considerable loss of the vitamin A value that may occur in storage of feed. (**195**) This loss is much reduced by including an approved antioxidant in the mash.

In the previous report of the committee of the National Research Council, instead of stating the minimum requirements, recommended allowances were given, which included considerable margins of safety. In that report, allowances of 2,000 U.S.P. Units of vitamin A value per pound of feed were recommended for starting and growing chicks, and 3,300 U.S.P. Units per pound of feed for hens. These allowances seem to provide a sufficient margin of safety in making up practical rations. Roosters apparently need much less vitamin A value than do layers.

Numerous experiments have been conducted to determine the minimum or the optimum amounts of vitamin A value for chicks, growing chickens, and for laying hens.[13] In these studies a vitamin A content somewhat lower than the requirements now stated by the committee has generally been satisfactory, except for hens producing hatching eggs. For example, the actual requirement of chicks to 8 weeks of age has been only 500 to 800 U.S.P. Units of vitamin A value per pound of feed.

Laying hens require a higher content of vitamin A value in their feed in very hot weather than when it is cooler.[46] This is chiefly because they then consume less feed.

It is especially important to have an ample supply of vitamin A in the rations of breeding hens, because the amount of vitamin A in eggs depends on the vitamin A value of the ration. If the hens are supplied with only a sufficient amount for satisfactory market egg production, the vitamin A content of the eggs may not be great enough to provide an optimum supply for the developing chicks. For this reason, some investigators recommend a more liberal supply for breeding hens than is needed for the production of market eggs.

From the standpoint of the consumer, rations having an ample supply of vitamin A are highly desirable for all laying hens, because of the higher vitamin content of the eggs.

If poultry are on pasture or are supplied with fresh green feed, they will have an abundance of vitamin A, because of the high carotene content of green forage. (**196**) When they get no fresh green feed, care must always be taken to provide sufficient vitamin A value.

To insure an adequate supply of vitamin A, a sufficient amount of carotene or vitamin A supplement should be included in poultry mashes. Alfalfa meal of good quality not only supplies carotene, but it also furnishes vitamin K and it helps furnish B-complex vitamins, including one of the unidentified vitamins. (**1228**)

Synthetic vitamin A is now the cheapest source of vitamin A for formula feed manufacturers, but it does not supply the other vitamins furnished by alfalfa meal. Fish liver oils and concentrates commonly furnish not only vitamin A, but also vitamin D_3.

When chicks are fed a ration severely deficient in vitamin A, symptoms of the lack will begin to appear in about 3 weeks. Growth is greatly retarded, and the chicks show general weakness, emaciation, staggering gait, and ruffled plumage. The eyes also become watery and inflamed. The resistance to infection is reduced and mortality is greatly increased. In older birds the eye symptoms often become more acute, and in advanced stages the sight may be destroyed. A deficiency of vitamin A often causes symptoms resembling roup, the trouble being called "nutritional roup." In this there is a sticky or cheesy discharge from the eyes and a sticky discharge from the nostrils.

1518. Effect of feed on color of egg yolks and body tissues.—Certain yellow substances which are transferred from the feed greatly affect the color of egg yolks and of the shanks, beaks, skin and body fat of poultry. The effect is chiefly produced by xanthophylls, which are somewhat similar to carotene, but which have no vitamin A value. (**197**)

Xanthophyll is transferred to egg yolks and to body tissues to a much greater extent than is carotene. Most of the carotene that is assimilated by poultry is converted in the body to vitamin A, which has but very little yellow color. Carrots and sweet potatoes, which are rich in carotene but which have relatively little xanthophyll, do not therefore have a marked effect on the color of egg yolks or body tissues.

The condition in poultry is therefore much different from that in cattle, in which yellow color in body fat or in milk is due to unchanged carotene assimilated from the feed, and not to xanthophyll.

Experiments have shown that a marked yellow color in egg yolks and body tissues is produced by green feeds, by good alfalfa hay or other legume hay, and by yellow corn and by-products made from yellow corn, such as corn gluten meal, corn gluten feed, and hominy feed. The other grains and the other common concentrates which are not made from yellow corn tend to produce light-colored yolks and body tissues. Yellow pigmentation is decreased by cod-liver oil and certain other fish oils, and also by meat scrap, fish meal, soybean oil meal, charcoal, or sulfur in the ration.

Because of the difference in the effect of various feeds, it is possible to regulate the color of egg yolks and of the shanks and skin of market poultry to suit the local demands, which vary in different regions. For example, light-colored yolks are preferred in the New York City market. Though alfalfa meal tends to produce a yellower color in egg yolks, the yolks are not too yellow, if not over 5 per cent of alfalfa meal is used in the laying mash.

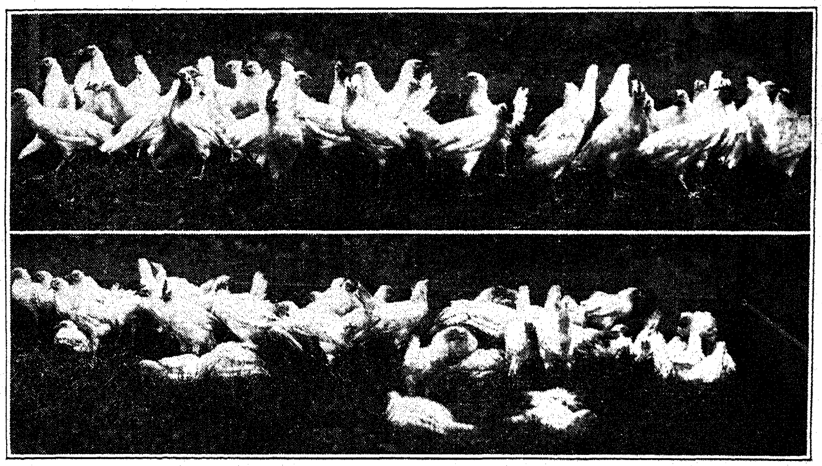
Certain feeds produce an undesirable color in egg yolks. If a ration for laying hens has more than about 5 per cent of ordinary cottonseed meal, the yolks are apt to develop an olive-green or brown color on storage, or to have dark spots. (**819**) A greater amount of low-gossypol cottonseed meal can be included in a ration without producing this discoloration. Also, adding 0.5 per cent of an iron salt to the feed seems to prevent it. (**812**) Shepherd's purse and penny cress, weeds which are members

of the mustard family, tend to produce olive-green yolks.

1519. Vitamin D; sunlight.—Poultry need much greater amounts of vitamin D than do the larger farm animals, per pound of liveweight or per pound of feed consumed. A deficiency of vitamin D causes poor growth, lameness, and other characteristic symptoms of rickets in chicks. (153) The first symptom of vitamin D deficiency in laying hens is the production of thin-shelled eggs, followed very shortly by decreased egg production. Hatchability is also greatly reduced. In laying hens suffering from vitamin D deficiency, the breast bone becomes soft and rubbery, because of withdrawal of calcium and phosphorus. Also, the bones of the legs and wings become fragile and are easily broken. Fowls may lose the use of their legs and squat in a characteristic manner, sometimes called "egg paralysis."

As has been explained in Chapter VII, the form of vitamin D in sun-cured forage and irradiated yeast, called vitamin D_2, has a very low efficiency for poultry, in comparison with the efficiency for man or four-footed animals. (202) On the other hand, vitamin D_3, which is the form in fish liver oils and in activated animal sterol, is equally effective for poultry and for other animals.

Sufficient exposure to the ultra-violet rays of sunlight which has not passed through window glass is effective in meeting the vitamin D requirements of poultry, just as in the case of other livestock. (201) When poultry do not have ample exposure to direct sunlight, it is essential to include a vitamin D supplement in the ration, or possibly to furnish the vitamin by irradiating the birds with ultra-violet light.



EFFECT OF LACK OF VITAMIN D ON CHICKS

The thrifty chicks in the upper illustration were raised in confinement, but cod-liver oil was included in the ration to furnish vitamin D. The chicks in the lower illustration received no cod-liver oil. They grew poorly, and many are severely affected with rickets. Some are paralyzed. (From Heuser and Norris, New York Station.)

The vitamin D requirements of poultry are expressed in International Chick Units (I.C.U.) of vitamin D_3. In the table of "*Nutrient requirements of chickens*" given earlier in this chapter, the requirement per pound of feed is 90 I.C.U. for starting chicks and growing chickens and 225 I.C.U. for hens. These are the estimated minimum requirements and do not include any margin of safety.

Experiments have shown that good growth and satisfactory egg production are secured on these amounts of vitamin D in rations when chickens have no ex-

posure to sunlight, provided that there are proper amounts of calcium and phosphorus.[13] However, rapid-growing strains of chicks seem to need considerably more of the vitamin for maximum gains and feed efficiency.[47]

Because of this and to provide ample margins of safety, in most of the rations recommended by the agricultural college poultry scientists greater amounts of vitamin D are included.[48] In mashes for chicks 270 to 300 or more I.C.U. per pound of feed are generally advised, and in mashes for laying hens, to be fed with grain, 500 to 800 I.C.U. per pound of mash.

When hens are fed, free-choice, mash and whole grains, especially corn or wheat, they sometimes eat so much of the grain that a deficiency of vitamin D occurs, unless the mash is well fortified with the vitamin.[49] When egg production drops for no other apparent reason, or when there are a considerable number of weak-shelled eggs, a deficiency of vitamin D may be suspected. If the trouble is due to this lack, it can be corrected within 3 weeks by supplying an ample amount of vitamin D supplement.

To avoid danger of a fishy flavor in meat, it is desirable to omit fish oils from rations for chickens during at least the last 2 weeks before they are sold for meat, and for not less than 8 weeks in the case of turkeys.

Instead of using a vitamin D supplement in rations for confined poultry, the vitamin may be supplied by exposing the birds to irradiation with ultraviolet light produced by sunlamps. Experiments have shown that sufficient irradiation with such lamps is as effective as adding a vitamin D supplement to the ration.[50] Which method will be more economical will depend largely on the local rate for electricity.

Relatively short exposure to direct sunlight may provide enough vitamin D for chicks. In Texas trials, only 1 hour of direct sunlight per week furnished sufficient vitamin D for chicks fed rations having ample calcium and phosphorus.[51]

Sometimes glass substitutes which permit the passage of more or less ultraviolet light are used in poultry houses instead of window glass. Unless carefully handled most such substitutes are short lived, and unless they are kept clean and taken out in summer they lose their effectiveness.

1520. Riboflavin.—Riboflavin is by far the most important of the B-complex vitamins in feeding poultry. This is because poultry have very high requirements for it. Also, there is not much synthesis of riboflavin by bacteria in the digestive tract, such as occurs in ruminants.

A deficiency of riboflavin causes poor growth of chicks and a characteristic paralysis of the legs and feet, known as "curled toe paralysis," or "nutritional paralysis." A chick suffering from this paralysis is shown in the illustration on Page 137. In laying hens a deficiency of riboflavin results in low hatchability of eggs. Considerably more riboflavin is needed for good hatchability than is required for egg production and maintenance of health.

It will be noted that the table of *"Nutrient requirements of chickens"* gives the following requirements of riboflavin per pound of ration: For chicks up to 8 weeks of age, 1.3 milligrams per pound of feed; for growing chicks from 8 to 18 weeks, 0.8 milligram; for laying hens, 1.0 milligram; and for breeding hens producing hatching eggs, 1.7 milligrams. (1498) These amounts are the estimated minimum requirements and do not include any margins of safety.

The riboflavin content of various feeds is discussed in Chapter VII. (212) The amounts of riboflavin in all important feeds are shown in Appendix Table V, so far as data are available.

Poultry on good pasture have plenty of riboflavin, for all fresh green forage has an abundant amount. For poultry not on pasture, care must be taken to supply enough riboflavin. This may be done by using feeds rich in riboflavin, such as milk by-products, alfalfa meal, or distillers solubles, or by adding to the ration a special vitamin supplement, such as

certain fermentation by-products or synthetic riboflavin.

Experiments have shown that synthetic riboflavin, which is now produced commercially, is just as effective as the natural riboflavin in feeds for supplying riboflavin.[13] However, synthetic riboflavin does not furnish other B-complex vitamins or unidentified vitamins, which are supplied by such feeds as milk by-products and alfalfa. For the best results, synthetic riboflavin should therefore be used in combination with feeds that furnish ample amounts of these other vitamins.

1521. Thiamine.—Thiamine is required by all poultry, but ample amounts are supplied by ordinary rations. A deficiency of thiamine in restricted rations causes loss of appetite, emaciation, poor digestion, general weakness, heart abnormalities, and frequently convulsions because of nerve degeneration. (211)

1522. Niacin.—Young chicks require more niacin per pound of feed than do older chicks or hens. This is apparently due to some synthesis of niacin by bacterial action in the digestive tract of older birds.

The committee of the National Research Council gives the requirement of niacin for chicks up to 8 weeks of age as 12 milligrams per pound of feed. (1498) Most rations for chicks that are otherwise satisfactory contain fully as much niacin as this.

In recent Wisconsin studies chicks from 6 weeks to 10 weeks of age were found to require only 3.5 to 6.0 milligrams of niacin per pound of feed.[52] The requirements of older chickens have not yet been determined. Since niacin can be formed in the body from tryptophan, a diet containing ample tryptophan reduces the niacin requirement.

A deficiency of niacin in purified experimental diets for chicks causes "black tongue," characterized by inflammation of the tongue and mouth cavity. Also, growth is retarded, feather development is poor, and occasionally scaly dermatitis of the feet and skin result. In turkey poults and sometimes in chicks, an experimental diet deficient in niacin causes a hock disorder similar to perosis.

1523. Vitamin B_{12}.—Vitamin B_{12} is essential for the growth of chicks and for hatchability of eggs. However, only an exceedingly small amount of the vitamin is needed. The special committee of the National Research Council in their report on *"Nutrient Requirements of Poultry"* states the tentative requirement of chicks to 8 weeks of age as only 0.004 milligram of vitamin B_{12} per pound of feed.[8] The tentative requirement of breeding hens producing hatching eggs is given as 0.002 milligram per pound of feed.

If hens receive a ration adequate in vitamin B_{12}, there is a marked carry-over of the vitamin in the egg to the chick.[53] On the other hand, when hens receive a ration deficient in vitamin B_{12}, it may cause high mortality in very young chicks.

More vitamin B_{12} is needed by hens kept on wire than for hens on litter, because the vitamin is synthesized by bacterial action in the feces in the litter. Heavy breeds of hens seem to require a larger amount of the vitamin than do Leghorns.

It has been pointed out in Chapter VII that much of the benefit from adding a supplement of animal origin to an all-plant-product ration for poultry is due to the vitamin B_{12} thus supplied. (220)

Before vitamin B_{12} was discovered and identified, the term *animal protein factor* was used for the factor or factors supplied by such supplements as fish meal, fish solubles, meat scrap, tankage, and dairy by-products. It is now known that these supplements furnish not only vitamin B_{12}, but also unidentified vitamins or factors, which are discussed later. (1528)

The approximate amounts of vitamin B_{12} in various feeds are stated in Appendix Table Vb, so far as data are available. Concentrated vitamin B_{12} feed supplements and antibiotic-vitamin B_{12} feed supplements are available commercially, which contain guaranteed amounts of vitamin B_{12}.

1524. Other B-complex vitamins.—Pantothenic acid, choline, pyridoxine, folic acid (or folacin), and biotin are all

required by poultry. These vitamins are discussed in some detail in Chapter VII, and the effects of a deficiency in experimental rations are stated.[13] (214–219) The amounts of each of these vitamins required by young chicks are stated in the previous table of *"Nutrient requirements of chickens."* (1498) The requirements of hens are also given in this table, so far as data are available.

Fortunately, most poultry rations that are adequate in other nutrients furnish sufficient amounts of each of these vitamins.

Pantothenic acid and choline supplements are added to some formula mashes for chicks, for broilers, or for hens producing hatching eggs, to make sure there will be no possible deficiency of these vitamins. As stated in Chapter VII, betaine can partially replace choline in the diet. (218)

1525. Yeast.—Brewers' dried yeast and other forms of yeast are rich in riboflavin and other B-complex vitamins, and may be used to supply these vitamins in poultry rations.

In most of the experiments in which dry yeast has been added to poultry rations containing an ample supply of riboflavin and other B-complex vitamins, or in which such rations have been fermented with yeast, there has been no benefit from the use of yeast.[54]

1526. Vitamin E.—Detailed information is given in Chapter VII concerning vitamin E, or tocopherols, in livestock feeding. (223) As there stated, a lack of vitamin E in experimental rations purposely made deficient in the vitamin causes the disease called nutritional encephalomalacia, or "crazy chick disease." The chick suddenly becomes prostrated, lying with legs outstretched and toes bent. The head is drawn back and often twisted to the side. Before the final stage, its movements are frequently incoordinated.

In mature fowls, a prolonged vitamin E deficiency in an experimental ration causes lowered hatchability of eggs and sterility of males.

The definite requirements of poultry for vitamin E have not yet been determined accurately, because most good rations seem to supply a sufficient amount of the vitamin. According to Titus, the requirement of vitamin E by chicks is probably not less than 6 milligrams per pound of feed, and a satisfactory allowance is 9 milligrams.[55]

In Connecticut experiments chicks fed an experimental ration having only 3 milligrams of vitamin E per pound made good growth and no nutritional encephalomalacia developed.[56] However, adding 2 per cent of fish oil to this ration as a stress factor produced heavy mortality from this disease. This was due to the destruction of vitamin E by the highly unsaturated fats in the fish oil.

The nutritional encephalomalacia was prevented when 0.05 per cent of an antioxidant (diphenyl-p-phenylenediamine, DPPD) was added to the ration, along with the fish oil. This prevented the destruction of vitamin E.

New York studies have shown that on a ration low in vitamin E, White Leghorn chicks are more resistant to nutritional encephalomalacia than are Rhode Island Red or Barred Plymouth Rock chicks.[57]

Information is given in Chapter VII concerning the occurrence of vitamin E in different kinds of feeds. (223) The approximate content in various feeds is given in Appendix Table Vd, so far as data are available. If there has been trouble from nutritional encephalomalacia on a practical ration, a feed should be added that is rich in vitamin E, or else a tocopherol concentrate. DPPD or another suitable antioxidant should also be included in the mash, to prevent the destruction of vitamin E during storage.

1527. Vitamin K; hemorrhagic disease.—The need by chicks for vitamin K to preserve the clotting power of the blood is discussed in detail in Chapter VII. (225) A lack of this vitamin in the feed of chicks greatly delays the clotting time of the blood and may produce serious hemorrhagic disease. Chicks fed a ration deficient in vitamin K may bleed to death from any injury or bruise which causes rupture of blood vessels. In severe vitamin K deficiency, hemorrhages may

occur in any part of the chick's body. These hemorrhagic conditions seem to be the only symptom of the lack of the vitamin.

Although this trouble is readily produced in chicks fed an experimental ration low in the vitamin, symptoms of deficiency are not caused when hens are fed the same ration. This is probably because more vitamin K is synthesized by bacterial action in the intestine of the older birds. However, if hens are fed a ration deficient in vitamin K, chicks hatched from their eggs may bleed seriously from minor wounds, such as wing banding.

In the report on *"Nutrient requirements of chickens"* the special committee of the National Research Council gives the tentative requirement of vitamin K for chicks to 8 weeks of age as 0.18 milligram per pound of feed.[8] Only 1 to 2 per cent of alfalfa meal of good quality usually furnishes ample vitamin K in poultry rations, even for chicks.[58]

However, as is stated in Chapter VII, the requirement of the vitamin is considerably increased if there is added to the ration a high level of certain drugs, such as sulfaquinoxaline (for coccidiosis control) or arsonic acid derivatives (as a growth stimulant). Hemorrhagic trouble may then occur in chicks on a ration that would be otherwise satisfactory.

In such cases the trouble can be prevented by increasing the percentage of alfalfa meal, by adding green feed, or by adding to the ration menadione or menadione sodium bisulfite (a water-soluble form of menadione). Such an addition should also be made to a high-energy ration for chicks which contains no alfalfa meal, or an insufficient amount to prevent hemorrhagic disease.

1528. Unidentified vitamins or factors.—Recent investigations have shown that in addition to the known and identified vitamins, certain unidentified vitamins or factors are also required by chicks and turkey poults. These have been discussed in Chapter VII. (222)

Older birds have less need of these vitamins or factors, probably because certain amounts are synthesized by bacterial action in the intestine. However, if hens or turkeys producing hatching eggs are continuously fed a ration deficient in these substances, the chicks or poults from their eggs will be depleted in these compounds. They will then not make normal growth unless their ration has ample amounts of these unidentified substances.

For this reason, in the investigations to study these mysterious substances, chicks or poults are generally used which are from dams that have been fed rations lacking these vitamins or factors. Chicks or hens kept on wire show a much greater need of these substances than do those kept on litter, especially deep litter. This is undoubtedly because of the synthesis of these compounds in the litter.

Painstaking experiments have shown that at least 3 or 4 unidentified vitamins seem to be required by chicks.[59] In addition, an unknown trace mineral or combination of minerals is evidently needed.

One of the unidentified vitamins, called the fish solubles factor, or the liver factor, is supplied in largest amounts by fish solubles, fish meal, liver meal, penicillium mycelium meal, and some other fermentation products.[60] Meat scrap has somewhat less, and there is a still smaller amount in dairy by-products.

A second unidentified vitamin, called the distillers solubles factor, is furnished by grain or molasses distillers solubles and yeast.[61]

A third, called the grass juice factor, or the alfalfa factor, is supplied by fresh green forage, dairy by-products, brewers' dried yeast, and alfalfa meal.[62] Soybean oil and grain or molasses fermentation solubles have small amounts.

Whey apparently furnishes both the grass juice factor and the fish solubles factor. Some investigators consider that the factor present in dried whey, other dairy by-products, and certain other feeds is a distinct factor.[63]

In recent New York and Texas studies chicks from hens fed a ration deficient in unidentified vitamins or factors were given purified experimental diets supplying ample amounts of all known nu-

tritive essentials.[64] The chicks were kept on wire to prevent their obtaining the unidentified substances from the feces.

The addition of dried distillers solubles produced a marked increase in growth rate of these chicks. Surprisingly, when the ash of distillers solubles was added to the experimental diet, the growth was also increased, although to a considerably less extent than by the distillers solubles. This indicated that part of the benefit from the addition of distillers solubles was due to some trace mineral or to a mixture of minerals supplied by the distillers solubles. In the New York studies, this effect was not produced by the addition of any of the recognized essential trace minerals, or of several other minerals tested.

In a recent Illinois experiment the ash of fish meal improved the growth rate of chicks fed a purified diet lacking unidentified vitamins or factors.[65] On the other hand, in another Illinois trial the ash of distillers solubles did not consistently increase the growth of chicks fed such a diet, while distillers solubles itself uniformly improved growth.[66]

The greatest improvement in growth of chicks is apparently not produced unless all of the unidentified vitamins or factors are present in the diet. It is therefore important to see that a mash for chicks has sufficient amounts of the feeds or supplements that furnish these essentials.

The amounts of these unidentified vitamins or factors required for maximum growth by chicks have not been determined, because these substances have not been separated and identified. The example rations for poultry in Appendix Table VII show the approximate amounts needed of the feeds which supply these vitamins or factors.

1529. Anti-gizzard-erosion factor.—Sometimes the lining of the gizzard of chicks becomes eroded in spots, apparently because of a nutritive deficiency.[67] Unless the erosions are severe, the growth of the chicks does not seem to be affected.

If the ration contains sufficient of certain feeds, this trouble is largely prevented. The anti-gizzard-erosion factor is supplied by alfalfa meal, green forage, wheat bran and wheat middlings, oats and oat hulls, and liquid skimmilk, buttermilk, or whey, but apparently not by dried dairy by-products. Bile and cholic acid, a bile ingredient, are especially rich in the factor. There seems to be less of the trouble if the ration has ample vitamin B_{12}.

1530. Net-energy values, or productive-energy values.—The only extensive experimental data concerning the net-energy values of feeds for poultry were secured by Fraps and associates at the Texas Station some years ago in investigations with chicks.[68] These experiments were conducted by the carcass-analysis method described in Chapter II. (72) In this method the bodies of chicks are analyzed after being fed the experimental rations for several weeks. From the amounts of protein and fat stored in the body, the storage of energy is determined, and to this amount of energy is added the net energy used for maintenance.

In this manner the net-energy values of a considerable list of feeds were determined directly. From the data thus secured, Fraps computed *production coefficients* for computing the net-energy values of feeds from the chemical composition, and published a table giving these net-energy values for many feeds. He used the term *productive energy* instead of net energy for these values, which are the same as net-energy values.

For poultry feeding, net-energy or productive-energy values are now most commonly stated in terms of Calories (large calories) per pound of feed. For other stock, net-energy values are usually expressed in terms of therms per 100 lbs. of feed (1,000 Calories equal 1 therm.)

Recently, Titus has computed and published productive-energy values for the important poultry feeds, by using Fraps' data and later data concerning the composition of feeds and their digestibility by poultry.[69]

The original Fraps' productive-energy values for the most important poultry feeds and the revised values com-

puted by Titus are given in Appendix Table XI.

The investigations by Fraps and associates showed that corn, wheat, the grain sorghums, and barley had even higher productive-energy values for chicks than these grains have for ruminants. Thus, ground dent corn of Grade No. 2 had a productive-energy value of 1,092 Calories per pound, ground wheat a value of 1,013 to 1,024 Calories per pound, and ground grain sorghums fully as high values as that of corn.

In contrast to these grains, which are low in fiber and high in digestibility, were feeds high in fiber or otherwise poorly digested by poultry. Thus, oat hulls or cottonseed hulls supplied no productive energy to chicks. Alfalfa meal furnished only 261 Calories per pound, and alfalfa stem meal but 185 Calories per pound.

Though dried beet pulp is not very high in fiber, its carbohydrates are digested poorly by poultry, and it supplied but 220 Calories of productive energy per pound. The productive-energy value of wheat bran was only 478 Calories per pound, while that of white shorts was 983 Calories, and that of wheat red dog 1,020 Calories.

Most of the protein-rich supplements had much lower productive-energy values than did the cereal grains. The productive-energy value of 43-per-cent-protein soybean oil meal was 674 Calories per pound; of 43-per-cent-protein cottonseed meal, 694 Calories; and of 50-per-cent-protein meat-and-bone scrap, 724 Calories. Though dried skimmilk and dried buttermilk have a high value for poultry because of the excellent quality protein and the vitamin content, their productive-energy values were surprisingly low, being only 525 Calories per pound for dried skimmilk and 707 Calories for dried buttermilk.

The productive-energy values, or net-energy values, determined by Fraps should be considered as only very approximate. This is because the investigations were conducted before the modern knowledge had been gained concerning the vitamin requirements of chicks. It seems possible or probable that some of the experimental diets used in these studies were deficient in some of the vitamins now known to be essential for maximum growth of chicks.

It has not yet been determined whether various feeds have approximately the same productive-energy values for laying hens as for chicks.

1531. Calorie-protein ratio.—It has been pointed out previously in this chapter that chickens fed a high-energy ration need a slightly higher percentage of protein than do those fed a ration lower in energy. (**1499**) Formula feed manufacturers therefore give attention to the ratio, or proportion, between the Calories of productive energy, or net energy, and the percentage of protein in high-energy mashes.

For example, a chick mash furnishing 900 Calories of productive energy per pound and containing 20 per cent total protein has a Calorie-protein ratio of 45.0 : 1.

From his experiments at the University of Maryland and the results of other investigations, Combs recommends that broiler starter rations should have a Calorie-protein ratio of approximately 42 : 1, and a broiler finishing ration, a ratio from 48 to 50 : 1.[70] For hens laying about 200 eggs a year, he advises a Calorie-protein ratio of 62 : 1, and for hens laying 300 eggs a year, a ratio of 56 : 1.

1532. Metabolizable energy.—Metabolizable energy values of poultry rations or feeds can be determined much more easily than productive-energy values, or even total digestible nutrients. All that is necessary is to find the gross energy content of the daily ration, and to subtract from the gross energy the amount of energy excreted daily in the feces. In poultry there is no appreciable loss of energy in combustible gases produced in the digestive tract, as in the case of cattle. (**76**) Therefore no correction is necessary for this loss.

In recent New York experiments by Hill and Anderson the metabolizable energy values of several feeds and rations have been determined in experiments

with chicks, and also the productive-energy values of certain rations have been ascertained by the Fraps' slaughter method.[71] In these studies it was found that in various experiments the productive energy of the same ration differed widely in different tests. On the other hand, there was good agreement in the metabolizable-energy values determined in different experiments with the same ration.

These studies indicate that metabolizable-energy values are more reliable than productive-energy values for chicks. Therefore, in the future they may prove more useful. Thus far, however, productive energy has been used chiefly by poultry scientists in estimating the energy values of feeds or rations for poultry.

Appendix Table XI gives the metabolizable-energy values for certain feeds, as determined in these New York experiments. Also, this table gives the metabolizable-energy values of other important poultry feeds, computed by Titus from data by Fraps and others.[69]

1533. High-energy rations.—High-energy rations are now commonly used by commercial poultrymen for chicks and broilers, because more rapid growth is produced and less feed is required per pound of gain. The high-energy, or high-efficiency, rations were first developed by Singsen and Matterson of the University of Connecticut for broiler production.[72] Such rations are now widely used not only for broilers, but also for layers and often for rearing pullets.

High-energy mashes for chicks and broilers generally provide 900 or more Calories of productive energy per pound. In order to secure this high-energy content, 50 to 60 per cent or even more of the mash usually consists of corn or corn and wheat. Grain sorghums can be used in place of these grains, with suitable vitamin A supplementation.

Only high-grade, low-fiber dehydrated alfalfa is used in such mashes. To reduce the fiber content and thus increase the energy value, no alfalfa is included in some high-energy broiler mashes. The vitamins that would be supplied by alfalfa must then be furnished by special vitamin supplements.

Since corn is low both in niacin and in tryptophan, supplementary niacin is needed, unless sufficient is furnished by the other feeds. In the Connecticut high-energy formulas for broiler mashes, choline is also added.

Although high-energy broiler mashes necessarily cost more per ton than mashes lower in productive energy, numerous experiments have shown that they are generally more economical and profitable.[73] This is because the gains are more rapid on such a ration, considerably less feed is required per pound of gain, and superior carcasses are produced. The surprising efficiency that can be secured in broiler production on modern high-energy rations, completely supplemented, has been cited previously in this chapter. (1495)

Experiments have also shown that high-energy rations are superior to rations lower in energy for high egg production, especially in cold weather.[74] When it is cold, hens fed a low-energy ration cannot consume enough feed to obtain sufficient energy for continued high egg production and maintenance of their weights.

In recent New York experiments, compared with a high-energy ration supplying 930 Calories of productive-energy per pound, a decrease of 100 Calories per pound in productive-energy increased the amount of feed required per dozen eggs by 12 per cent.[75]

Most experiments have shown that high-energy rations are efficient for raising replacement pullets.[76]

Formulas of high-energy mashes for chicks, broilers, and hens are given in Appendix Table VII.

1534. Fiber.—Because all chickens have very limited ability to digest fiber, their rations must be relatively low in it. Under usual conditions, the fiber content of rations should not be more than about 5 per cent.[77] High-energy mashes generally do not contain more than 4 per cent of fiber.

The growth of chicks fed an experimental diet containing practically no

fiber is increased by adding to it a small percentage of fiber.[78]

Experiments have shown that when as much as 30 per cent of a feed very high in fiber, such as finely-ground oat hulls or peanut hulls, is added to a ration, chicks will eat much more feed and may make nearly normal gains.[79] However, the amount of feed required per pound of gain is greatly increased. Also, on the high-fiber ration considerably less fat is deposited in the body, thus reducing the energy content of the flesh.

If a bulky, high-fiber mash is pelleted, the density is much increased, and the birds can consequently consume more of it. Normal growth can therefore be secured on a pelleted ration which is higher in fiber than would produce good gains, if it was not pelleted. However, much more feed will still be required per pound of gain than on a high-energy ration.

On rations very low in fiber there is more tendency for feather-picking or cannibalism to develop than on rations having more fiber. Including in the ration certain feeds rather high in fiber, especially oats, reduces this tendency, but it of course lowers the energy value.

On high-energy, low-fiber rations it is sometimes necessary to prevent feather-picking by such measures as darkening the house and using ruby-light, or by debeaking the birds (removing the tip of the upper mandibles of the beaks).

1535. Antibiotic feed supplements.—A general discussion of antibiotic feed supplements has been given in Chapter XXIII. (**966**) It is there pointed out that most of the antibiotic supplements on the market not only contain an antibiotic or a mixture of antibiotics, but also supply vitamin B_{12}. A supplement of this kind is called an antibiotic-vitamin B_{12} feed supplement. The effect of such a supplement may be due, of course, both to the antibiotic and also to vitamin B_{12}.

A great number of experiments have been conducted to determine the effects on chickens and also upon turkeys of an antibiotic supplement or of an antibiotic-vitamin B_{12} feed supplement. Most of the studies have been with chicks or broilers, but several experiments have been with hens or growing pullets. Several tests have been conducted with turkeys, but much less information has been secured with ducks or geese.

The increase in growth rate of young birds produced by an antibiotic supplement is greatest for turkey poults, somewhat less, but still important for chicks and goslings, and least for ducks.[80] The use of antibiotic supplements for turkeys, ducks, and geese is discussed in the next chapter.

1536. Antibiotic supplements for chicks and broilers.—In most, but not all, of the experiments with chicks and broilers, the addition to a ration of an antibiotic supplement or an antibiotic-vitamin B_{12} feed supplement has produced an appreciable increase in the rate of growth.[81] The effect has been most marked up to about a month of age.

The growth stimulation has generally been greatest when the supplement has been added to a ration containing no protein supplements of animal origin, or to a ration low in vitamin B_{12} and the unidentified vitamins or growth factors. However, significant growth increases have usually resulted from adding such a supplement to an already excellent ration, containing some fish meal, fish solubles, meat scrap, or dairy by-products.

When the antibiotic supplement has improved the gains, the increase has generally not been more than 10 to 15 per cent. The feed efficiency, or the amount of feed required per pound of gain, has been affected much less than the rate of gain, but it is commonly improved slightly.

The probable causes of the growth stimulation by an antibiotic supplement have been discussed previously.[82] (**966**)

The antibiotic supplements that have been most commonly used for poultry are procaine penicillin, aureomycin (chlortetracycline), terramycin (oxytetracycline), and bacitracin. Streptomycin has been somewhat less effective in most of the tests in which it has been compared with these other antibiotics.[83] Less information is available concerning the

effect of other antibiotics. Some others have been much less effective than those mentioned, and certain ones have produced no growth stimulation or have even depressed gains.

In using an aureomycin, terramycin, or bacitracin feed supplement, usually sufficient is added to the ration to supply about 10 grams of the antibiotic per ton of feed. Less procaine penicillin is needed, only about 4 grams of the antibiotic per ton of feed being enough. To control disease, sometimes a high level of an antibiotic supplement is used (50 grams or more of the antibiotic per ton of feed).

Although an antibiotic supplement has the most marked effect on chicks up to about a month of age, in broiler production, where rapid gains are important, the supplement should be fed continuously.

It has been mentioned earlier that in certain recent experiments chicks kept under practical conditions have responded much less, or not at all, to an antibiotic supplement, while in previous years the growth increase on similar rations had been marked.[84] (**966**) This difference in results may be explained by a reduction in harmful bacteria brought about by the continued use of an antibiotic supplement in the previous years.

In some experiments chicks raised in new quarters, where there have been no birds before, have shown no growth stimulation from an antibiotic supplement.[85] In these trials the antibiotic supplement has increased the growth of other chicks fed the same rations in old quarters. These quarters apparently carried some contamination with undesirable bacteria.

A combination of antibiotics has been no more effective than a single effective antibiotic in most of the experiments in which such a comparison has been made.[86] However, some poultry scientists believe there are fewer failures to obtain a beneficial effect when a combination of antibiotics is used under practical conditions.[87]

The growth of chicks has not been increased in certain trials by implanting an antibiotic pellet under the skin, instead of including the antibiotic in the feed.[88]

1537. Antibiotic supplements for hens or growing pullets.—The results have differed decidedly in the various experiments in which an antibiotic supplement has been added to rations for layers. In most of the trials the egg production has not been increased by adding an antibiotic to a ration which was nutritionally complete.[89]

On the other hand, if hens are fed an all-vegetable-product ration, an antibiotic-vitamin B_{12} feed supplement may appreciably increase both egg production and hatchability. These effects may be due more to the additional B_{12} supplied, than to the antibiotic.[90]

Also, if the egg production of well-bred pullets or hens has declined to an unsatisfactory level on a supposedly adequate ration, an antibiotic supplement may bring a marked increase in egg yield.[91] In such a case, using a high level of the antibiotic supplement is desirable.

The early growth of chicks may be increased when an antibiotic supplement is added to the ration for rearing pullets.[92] This may also result when a ration for hens that is low in vitamin B is supplemented with an antibiotic.[93]

1538. Arsonic supplements.—In the discussion of arsonic supplements in Chapter VII, it was explained that certain derivatives of arsonic acid have generally had an effect somewhat similar to that of an antibiotic, when added to a good ration for chicks or poults.[94] (**967**) In some cases the arsonic supplement even stimulates growth slightly when added to an efficient ration containing an effective antibiotic supplement. Also, the amount of feed required per pound of gain is usually reduced very slightly.

An arsonic supplement may not be beneficial if the level of harmful bacteria or of disease is very low. For example, there was no benefit from adding either an arsonic supplement or an antibiotic to rations for chicks in recent Wisconsin tests.[95] In previous trials these supple-

ments had increased the growth when added to similar rations. Apparently, the continued use of the supplements had reduced the level of harmful bacteria so that a benefit was no longer secured from either type of supplement.

Although the increase in rate of gain and in feed efficiency produced under usual practical conditions by using an arsonic supplement is commonly small, adding the supplement may be profitable. This is because of the very small amount of the supplement needed in the ration. For example, a common rate of addition of certain arsonic supplements is only 0.1 lb. per ton of feed. This addition costs only about 40 cents per ton.

Arsonic supplements commonly added to commercial feeds are arsanilic acid (4-aminophenyl arsonic acid), "3-nitro" (3-nitro-4-hydroxyphenyl arsonic acid), and 4-nitrophenyl arsonic acid. (**967**).

Since the arsonic compounds are toxic in excessive amounts, proper care should be taken to secure even mixing. When properly mixed, meat will not contain excessive amounts, although regulations require that arsonics must not be fed for 5 days prior to slaughter.

Additions of these compounds to rations of growing pullets or of hens has given varied results. In some trials no benefit was secured, while in others, pullets have come into production a few days earlier and hens laid a few more eggs.[96] Eggs from hens fed such compounds contain only trace amounts of arsenic, well below toxic levels.

1538 (a). Furazolidone.—Significant improvements in egg production, with no effect on hatchability and fertility were secured in Arkansas experiments by the addition of dietary furazolidone (N.F. 180) to laying and breeder hen rations, often with a reduction in feed required per dozen eggs. Disease levels present as well as management procedures coupled with the economics of the situation will dictate whether or not such additions are practical.

1538 (b). Enzymes, water treatment of grains.—A recent development is the finding that soaking or adding enzymes to certain cereal grains, such as barley, pearled barley, oats and rye, improves their value for poultry according to work by Washington and Oregon. This discovery is still too new to properly evaluate it.

1539. Surfactants.—Several trials have been conducted during recent years to find whether adding certain surfactants to a ration for chicks would increase the growth.[97] As has been stated in Chapter VII, in most of the tests surfactants have not stimulated growth, or else have been less effective than a suitable antibiotic. (**967**) In trials where the growth has been increased, the effect has usually been after the chicks were 5 to 8 weeks old.[98]

1540. Hormones.—The hormone that has been used most widely in practical poultry production is diethylstilbestrol, a synthetic female sex hormone. (**54**) Administering this hormone, commonly called stilbestrol, to cockerels or roosters a few weeks before slaughter has a feminizing effect.[99] It increases the fatness and tenderness of the meat and improves the market finish. Sometimes the hormone is used for broilers of both sexes during the finishing period.

Cockerels treated with the hormone have some of the characteristics of capons, and are called "caponettes," or "hormonized fryers."

The stilbestrol is administered by implanting under the skin of the head or upper neck a pellet or else a paste which contains the proper dose of the hormone. The hormone is absorbed slowly and therefore only one treatment is needed.

To hasten the fattening, sometimes not only are the birds implanted with stilbestrol, but also 0.15 to 0.20 per cent of thiouracil is added to the ration during the finishing period. This drug slows down the action of the thyroid gland. It thus reduces the rate of metabolism in the body and increases fat deposition.

The feeding of stilbestrol, by adding it to the ration as in the case of fattening cattle, is apparently less effective with poultry than implantation. Such use of stilbestrol has not been authorized by the Food and Drug Administration.

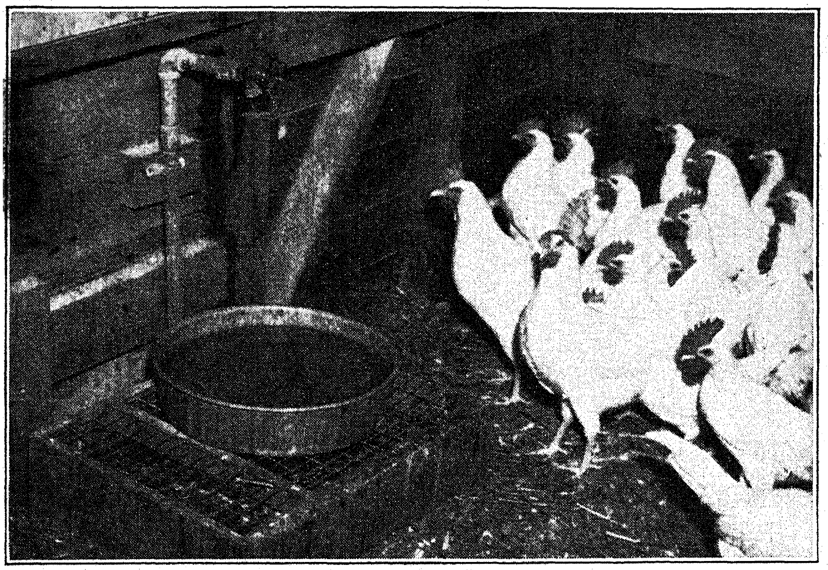
However, including in the ration another synthetic female sex hormone, dienestrol diacetate, has recently been authorized. Feeding this hormone has an effect similar to implanting stilbestrol.

Implanting stilbestrol in breeding stock decreases the egg production of pullets, and it delays sexual maturity of males and decreases the quantity of semen produced.[100] In an Ohio experiment implanting broody hens with stilbestrol broke up the broodiness in most cases.[101]

Adding *thyroprotein,* or iodinated casein, to poultry rations has sometimes been recommended to increase body metabolism. (54) However, in most of the experiments which have been reported, this supplement has not increased egg production or produced a significant increase in the growth of chicks.[102] Thyroprotein supplementation may increase the thickness of the egg shells, but it tends to reduce the body weights of hens.

1541. Water.—A constant supply of fresh, clean water is an essential for all classes of poultry. Because they drink only a small amount at a time, they will not drink sufficient water for good results when given access to it only once or twice a day, which is often done with larger farm animals.

In cold weather some method should be used to keep the water from freezing. Also, there may be a benefit in taking the chill off the water in cold weather, so that hens will drink more.[103]



A Simple Arrangement for Watering Chickens

The platform covered with wire mesh prevents the litter becoming wet around the waterer. (From New York State College of Agriculture, Cornell University.)

The watering arrangement should be so constructed that the birds cannot roost upon it and foul the water with their droppings, and should be high enough to prevent litter being scratched into it. For chicks a vacuum fountain is desirable. The simplest form of such a fountain is simply a jar filled with water and inverted in a shallow pan. As the chicks drink the water from the pan, air enters the jar and water flows out into the pan until the water level rises.

Poultry consume about 2 to 3 lbs. of water per pound of air-dry feed eaten. The water consumption is greater on a

ration high in protein than on one lower in protein.[104] Also, it is greater on a ration containing meat scrap, fish meal, or dried whey than on an all plant-product ration.[105]

The daily water consumption of laying hens will depend on the rate of egg production and the air temperature. Heavy layers require considerably more than poor layers. Hens may drink twice as much water a day in summer as in winter. The amount of water consumed by hens in a year has ranged from about 116 lbs. to 175 lbs. or more in tests that have been conducted.[106]

II. Other Problems in Poultry Husbandry

1542. Preparation of feed.—Poultry, except young chicks, can utilize whole grain efficiently. Therefore the most common method of feeding laying hens and growing pullets is to feed whole grain separately, in addition to a mash made up of ground grain and protein, mineral, and vitamin supplements.

Sometimes layers are fed ear corn or small grain in the bundle, to save shelling or threshing or to force the hens to take more exercise. When grain is thus fed, it is, however, more difficult to know just how much grain the birds are getting, and often they are underfed.

For feeding as scratch grain or in hoppers, corn is often cracked, instead of being fed whole. Heuser advises that when whole corn is to be fed to layers, the growing pullets should be accustomed to whole corn on the range in summer.[30]

Grain should be ground to only a medium degree of fineness for use in poultry mashes. Fine grinding makes the mash less palatable, especially in the case of wheat or rye, which become pasty when finely ground. Finely-ground mashes were compared with coarser mashes in Ohio and Utah experiments with laying hens.[107] The feed consumption and egg production were greater with the coarser mashes, and also in the Ohio trials the mortality was less. Very finely ground mash sometimes causes necrosis and malformation of the beak in chicks, because of feed adhering to the beak.[108]

1543. Wet mash.—Before modern, efficient rations were developed for poultry, the feeding of mash in wet form to laying hens was much more common than at present. Chiefly because of the saving in labor, the most common practice now is to supply dry mash at all times, and to feed wet mash in addition to laying hens only when it is necessary in order to stimulate feed consumption. (**1566**)

Feeding wet mash is a frequent practice in fattening poultry, as is pointed out in the next chapter. Wet mash is also sometimes used for ducks.

1544. Pellets; crumbles.—Pellets or crumbles are often used for poultry. (**91**) Crumbles, also called "granules" or "crackles," are made by breaking large pellets into smaller pieces by a machine. The cost of making crumbles is less than that of making the very small pellets needed for feeding chicks.

The chief advantage of pelleted or crumbled feed is that there is less wastage by feed being blown out of outdoor feeders, or being scratched or billed out of the feeders by the birds. This advantage is more or less offset by the higher cost of such feed.

Also, if the entire ration is pelleted, or a large part of it, the trouble from feather-picking or cannibalism is often much increased. To avoid this, it may be necessary to "debeak" the birds, or use other measures to prevent the trouble.

There is usually more advantage in pelleting a ration high in fiber than in the case of a high-energy ration. This is because the density is much increased, and the birds can eat more of the feed. For example, in a California trial with layers and in a Canadian experiment with broilers, pelleting rations consisting largely of barley, improved the results.[109]

Several experiments have been conducted to determine the value of pellets or crumbles for poultry.[110] The results of the trials with chicks, broilers, or growing pullets have differed.[111] In some cases the gains and the feed efficiency

have been slightly better on pellets or crumbles than on mash rations. However, in other tests the results from mash-feeding have been just as good.

For laying hens, only the mash for feeding with scratch grain may be pelleted, or the complete ration may be thus processed. Sometimes, hens fed rations of mash and grain or all-mash are given a mid-day supplemental feeding of pellets to stimulate feed consumption.

In the experiments with hens, there has usually been no difference, or only a very slight difference in egg production when pellets have been fed instead of mash.[112] The hens fed pellets may eat somewhat more feed and therefore maintain their weights better.

1545. Methods of feeding poultry.—Several different methods of feeding poultry are used successfully by practical poultrymen. The results secured with various methods of feeding laying hens and growing birds are discussed in the following chapter.

The most common method of feeding laying hens is to full-feed a laying mash in hoppers or troughs, and to feed in addition the desired amount of whole or cracked grain. This is either fed as scratch grain in the litter, or else a limited amount of grain is fed in troughs or hoppers. When it is considered desirable to stimulate feed consumption, a wet mash may also be hand-fed once a day.

In the all-mash method of feeding layers, the entire ration is full-fed as a mixture in hoppers or troughs. Another method is the "cafeteria method" in which mash and grain are self-fed separately. When fed by this method, hens eat much more grain than mash. Therefore, to balance the ration, it is necessary to use a mash which is considerably higher in protein and richer in vitamins than is needed in the other methods. As mentioned previously, sometimes the mash is fed in the form of pellets, or cubes.

Chicks are usually full-fed their entire ration in mash form for the first few weeks. Chick-size scratch grain is then often fed in addition. In the fattening of poultry, the entire ration is generally fed as a wet mixture. A wet mash is also often used for ducks.

1546. Pasture versus confinement or bare range.—With the development of modern complete rations that fully meet all the nutritive requirements, it has become possible to raise poultry to maturity in confinement and without any access to range or to fresh green feeds. Likewise, laying pullets and hens can be kept successfully in confinement during the winter season and even throughout the year. Finally, the extreme in confinement has been reached in the battery method, in which laying fowls are confined individually in batteries made up of small compartments.

Extensive experiments have been conducted to compare good pasture, or range, with confinement or bare range for growing pullets[113] or for laying hens.[114] These experiments have shown that pullets which have been raised on fresh, uncontaminated pasture are usually more thrifty than those raised in confinement. Therefore, even when the fowls are to be confined during egg production, they should, if possible, be raised on good pasture. Raising pullets in confinement is, however, preferable to rearing them on a range that is badly contaminated with parasites and diseases.

Numerous experiments have shown clearly that for farm flocks of small or moderate size, it is more economical to provide clean, uncontaminated pasture during the growing season than to keep the layers in confinement. In the southern states, pasture makes an even greater saving than in the North, because good forage can be readily furnished during all or most of the winter.

In large-scale poultry production it is often difficult or impossible to provide good pasture for the layers. It then becomes necessary to keep them confined and to use great care in feeding a ration that fully meets all their nutritive requirements.

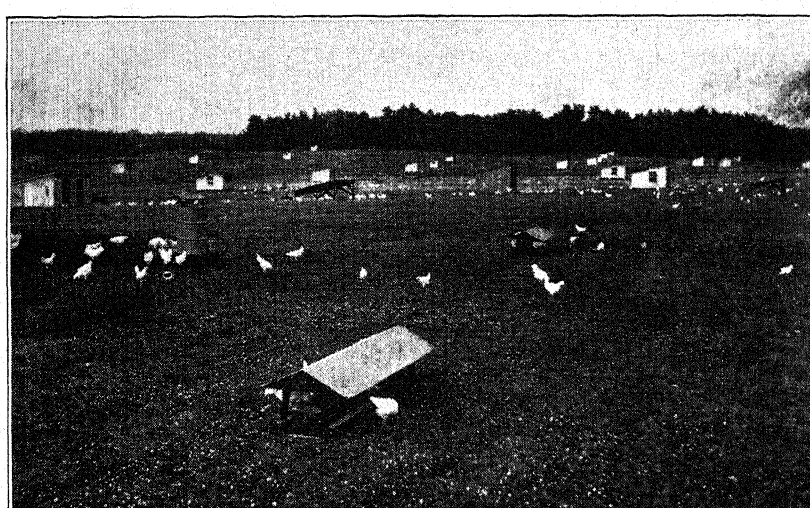
Good pasture for raising the pullets will usually save at least 5 to 10 per cent

of the total mash plus grain required, in comparison with feeding an efficient ration in confinement. There will be an even greater saving in cost, because there is a greater reduction in the amount of mash, which is more expensive, than in grain.

In addition, a much cheaper mash may be fed than is necessary without pasture. This is because good pasture is rich in protein and because pasture and direct sunlight combined fully meet all the vitamin needs. Information is given in the following chapter and in the example rations of Appendix Table VII concerning simple rations that are satisfactory for growing pullets and for laying hens which are on good pasture.

In most of the experiments with hens, the egg production has been higher on good pasture than in confinement or on bare range, and often the mortality has been less. In addition, there is a marked saving of feed by providing good pasture, and a cheaper mash, which contains less protein and vitamin supplements, may be used.

1547. Pastures for poultry.—Poultry will not eat much pasturage unless it is succulent and tender. To provide good pasture, the crop must therefore be kept growing actively over a long season. For this reason, the best poultry pasture is furnished by Ladino clover or other clovers, by alfalfa, by other legumes, or by such combinations as alfalfa and bromegrass or Ladino clover and grass. The various pasture crops are discussed in detail in Chapters XVI and XVIII. To stimulate new growth, the pasture should be mowed when necessary. (375)



Good Pasture Important for Raising Pullets

In addition to the saving of feed by the use of good pasture, pullets raised on fresh, uncontaminated pasture are usually more thrifty than those reared in confinement. (From Hurd, New York State College of Agriculture, Cornell University.)

Ladino clover or a combination of Ladino clover and grass is unexcelled for poultry pasture. (477) The crop is liked especially well by poultry, and it provides succulent pasturage over a long season.[115] In tests in the southern states, lespedeza, kudzu, and Dallis grass are among the pasture crops that have been very satisfactory.[116]

Kentucky bluegrass provides excellent pasturage in spring and fall, when it can be kept growing actively, but it often furnishes little forage in midsummer. In Kentucky experiments laying hens required about 20 per cent less concentrates on young bluegrass pasture in spring than was needed for hens in a dry

lot.[117] On the other hand, hens ate so little mature bluegrass that there was no appreciable saving of concentrates when hens were on such pasture.

1548. Clean, uncontaminated pasture essential.—To avoid serious infection with parasites and diseases, it is important to follow a careful pasture rotation system. The best plan is to provide pasture each year that has not been used by poultry the previous year, or even better, for two years. It is especially important to raise young stock on clean, uncontaminated pasture, from which the older poultry are fenced out.

It is a good plan to move the colony houses on pasture once a week to prevent killing out the pasture plants underneath. Another method is to move the feeders, waterers, and any range shelters, but not the colony houses.

An acre of good pasture should be sufficient for about 300 growing chickens or for 200 adult birds.

1549. Alfalfa meal or hay and substitutes.—The value of alfalfa meal or hay as a vitamin supplement for poultry has been discussed in Chapter XVI and also previously in this chapter. (**465, 1407, 1517, 1527, 1528**) Detailed information is given in Chapter XVI concerning the use of other kinds of legume hay in poultry rations.

Well-cured alfalfa hay and other legume hay not only supply carotene to meet the vitamin A requirements, but also help furnish B-complex vitamins and vitamins K and E, and one or more of the unidentified vitamins. In formula poultry mashes alfalfa meal is generally included as a vitamin supplement.

Although alfalfa or other legume hay is usually included in poultry rations in the form of meal, legume hay is sometimes supplied separately to farm flocks. In such cases it is generally fed as chopped hay, cut into one-half to one inch lengths and fed in wire baskets or containers.

Alfalfa or other legume chaff that accumulates where hay is pitched from a mow can be substituted for alfalfa meal. It may be fed dry, or it may be soaked and mixed with a wet mash.

Dehydrated young cereals or dehydrated vegetable wastes may be used as a substitute for alfalfa in poultry rations. (**586, 644**)

1550. Green feeds.—Before the use of alfalfa meal as a vitamin supplement became common, green feeds were often supplied poultry to furnish vitamins. When suitable pasture cannot be provided during the growing season, it may be beneficial to feed palatable green forage to laying hens and growing poultry, even when an efficient dry ration is used.

Green alfalfa, clover, or other legumes are excellent green feeds. Lawn clippings likewise rank high in vitamin content and palatability. Kale is used extensively for poultry in the Pacific Coast states. Rape is also often fed to poultry, but gives a dark color to the egg yolks. The waste parts of vegetables, such as cabbage leaves and carrot or beet tops, are good green feed for poultry. In the fall and winter, cabbage is often used as green feed. Cabbage is well liked by poultry, but it is not so rich in vitamins as green thin-leaved plants. Though cabbage is a rather expensive feed when grown for this purpose, the small and unmarketable heads make cheap feed for poultry.

Before modern poultry rations were developed, roots were used much more frequently than now for the winter feeding of poultry. Roots are well liked by poultry, but with the exception of carrots, they will not replace legume hay as a vitamin A supplement. Also, roots are much lower than legume hay in B-complex vitamins. In addition, they are usually an expensive source of nutrients in this country. (**627**)

When fresh green feed is fed to poultry, it is usually supplied at noon in such an amount as the birds will eat before night. A common allowance is 4 to 6 lbs. a day per 100 hens.[118] If hens are given all the palatable green feed that they will eat throughout the day, they may eat more than twice this amount. However, such a large allowance may make the egg yolks too deep in color to meet the demands of some markets.

1551. Silage.—Hay-crop silage, or so-called "grass silage," may be used instead of alfalfa meal as a vitamin supplement for poultry. (441) On the dry-matter basis, well-preserved hay-crop silage is even richer than good legume hay in carotene content. (437) Corn silage or sorghum silage is not generally fed to poultry, as it is too coarse and bulky.

When a ration for hens contains the usual amount of alfalfa meal, the egg production will not generally be raised by supplying hay-crop silage, but it does tend to increase the hatchability of the eggs.

As pointed out in Chapter XV, feeding more than 3 lbs. of hay-crop silage daily per 100 hens may produce dark-colored or greenish egg yolks. (441)

1552. Shelter.—To be healthy and profitable, poultry need quarters that are dry, well ventilated, well lighted, and free from drafts.[119] The poultry house need not be expensive, but should provide these essentials. Before building a poultry house, one should secure information from the state agricultural college or the local county agent concerning the type that is best adapted to the climatic conditions in the particular region.

On farms where poultry husbandry is an important enterprise, the laying hens are commonly kept in laying houses, and separate buildings are used for the young stock. These include brooder houses, movable colony houses, and range shelters. The simplest laying house is a one-story building with only one pen. For larger flocks laying houses with multiple pens are used. These are either long continuous one-story houses or multiple-story houses of two or more stories.

The laying house should be located on well-drained high ground, where the air movement will aid proper ventilation. Trees near the house will provide summer shade and also some protection from winter winds and storms. Unless the layers are to be kept in confinement, there should be ample range adjacent to the laying house.

In the house, about 3 square feet of floor space should be allowed for each hen of the smaller breeds, such as Leghorns, and 3¼ to 4 square feet per hen for the larger breeds. If the hens are confined in the laying house during the hot summer months, it is best to increase the allowance of floor space about one-half square foot per fowl. The normal decrease in size of flock from culling and mortality will often take care of this.

The house should be so arranged that it will be convenient to care for the poultry and with a minimum amount of labor. It is important that the house and all the fixtures be easy to disinfect. The fixtures—nests, perches, dropping boards, coops for broody hens, feed hoppers, etc.—should therefore be simple and removable. At least once a year and preferably twice a year, the house and all fixtures should be thoroughly disinfected.

1553. Air temperature and humidity.—California and Kansas experiments showed that an air temperature of about 65° F. is most favorable for high egg production.[120] A much higher or lower temperature tends to reduce the yield.

Poultry suffer from very hot weather.[121] (233) Feed consumption and egg production are much reduced. Also, the strength of the egg shells is lessened. High humidity increases the injurious effects of high air temperature.

In hot climates a method of cooling the birds is sometimes used. In California studies, with an air temperature of 90° F., mist-spraying laying hens for 30 seconds every 60 to 90 minutes was effective in reducing the body temperature.[122]

Shade in the pastures and good ventilation in the poultry houses are important in reducing the effect of hot weather.

1554. Litter.—The poultry house should be bedded with suitable litter, and this should be renewed when it becomes damp or filthy. Cut straw is used most often for litter. Other common kinds of litter are cut or shredded corn or sorghum stover, sawdust or wood shavings, ground corn cobs, peanut shells or hulls, cottonseed hulls, peat moss, and cane litter.

In Delaware studies various kinds of litter were given the following ranks for brooder houses: Peanut shells, first; followed in order by ground corn cobs, peat

moss, sugar cane litter, sawdust, shavings, cottonseed hulls, and corn stover.[123] Various kinds of mineral litter were less satisfactory.

Largely through investigations by Kennard, Chamberlin, and associates at the Ohio Station over several years, the use of "compost litter," or "built-up litter," has become common.[124] Other experiments have corroborated, in the main, their conclusions.[125] An important advantage of compost litter is that it makes it unnecessary to clean the house more than once a year, thus saving labor. Litter is also saved. Several broods of broilers, for example, can be raised on the same litter.

The compost litter is started in the fall with 4 to 6 inches of fresh litter fully covering the clean, dry floor. The litter is stirred up and leveled off about twice a week, and additional litter is added until the litter is 8 to 12 inches deep. It is important to stir the litter to prevent it from caking over the surface, and to mix the fresh droppings with the material below, which has been sanitized by bacterial action.

In cold, damp weather, it is beneficial to scatter hydrated lime, ground limestone, superphosphate, or gypsum over the surface before stirring it up. This keeps the litter drier and in better condition. Adding superphosphate also decreases the loss of nitrogen from the litter.

Any wet spots of the litter should be removed, as needed, and replaced by fresh material. Otherwise, none is removed until it may be necessary to take off some to prevent it becoming too deep for convenience.

Besides the saving of labor in using compost litter, there is a nutritional advantage. In the bacterial action that takes place, there is a considerable synthesis of B-complex vitamins, including vitamin B_{12}. Except when the ration has an ample supply of these vitamins, the growth of chicks or the egg production of hens may be appreciably increased by keeping them on compost litter. A disadvantage of compost litter is that sometimes there may be more trouble from coccidiosis or from round worms on such litter.[126] Also, inflammation of the cornea of the eye may occur in young chicks started on old compost litter, especially if it is damp. This is caused by ammonia in the litter.

1555. The egg.[127]—In several respects, an egg is similar to a grain, such as a kernel of corn. In each there is a germ, from which the new life develops, and each contains food for the nourishment of this germ. In the grain the stored food material is starch, fat, and protein, while in the egg the nutriment is stored in the form of protein and fat. While the grain must absorb much water for germination, the egg contains sufficient for its own development. Moreover, a much higher temperature is required for the hatching of the egg than for the germination of a seed.

An egg consists of five parts: (1) The shell; (2) the shell membranes; (3) the albumen; (4) the yolk; and (5) the germ. The *shell* makes up about 12 per cent of the weight of the entire egg. There are 2 layers of shell material, composed chiefly of calcium carbonate. On the outside of the shell is a thin protective coating, the cuticle, which protects the egg against bacterial invasion. This is similar in composition to the shell membranes inside the shell.

The *shell membranes* consist of 2 parchment-like layers, the inner one being the thinner. At the large end of the egg these layers separate, forming the air sac.

The *albumen*, or the white of the egg, which forms about 56 per cent of the weight, contains about 12 per cent dry matter, this being nearly all protein. When an egg is cooked, this albumen coagulates, or hardens.

The *yolk*, forming about 32 per cent of the egg, is enclosed in a delicate membrane which keeps it spherical in shape. The yolk contains an average of 48.7 per cent water, 16.6 per cent protein, 32.6 per cent fat, 1.0 per cent carbohydrates, and 1.1 per cent mineral matter.

The *germ* in the fresh-laid egg is a white speck about one-eighth of an inch in diameter on one side of the yolk.

The standard weight of hens' eggs is 2 ounces each, or 24 ounces to the dozen. Eggs weighing less than this sell at a discount on most markets. Those that weigh up to 26 ounces per dozen may sell at a premium, but extremely large eggs are not desired, as they are more apt to break when handled in ordinary containers.

QUESTIONS

1. Give an example of the increase in efficiency of production through modern rations and methods.
2. Tell how the digestive system of poultry differs from those of other farm animals.
3. Why are not rations for poultry commonly computed on the basis of digestible nutrients?
4. In what terms are feeding standards for poultry generally stated?
5. What percentages of protein are recommended in rations for: (a) Chicks up to 8 weeks of age; (b) chicks 8 to 18 weeks of age; (c) laying hens?
6. Discuss the importance of quality of protein for poultry.
7. Why should at least a small amount of a protein supplement of animal origin be included in a poultry ration, if possible?
8. Which amino acids may be deficient in practical, well-balanced rations for chicks?
9. Give an example of the way an amino-acid deficiency can be corrected.
10. Which pure amino acid is sometimes used as a supplement to practical rations?
11. Discuss the fat requirements of chickens.
12. What results have been secured by adding by-product animal fat to poultry rations?
13. Which minerals need special consideration in poultry rations?
14. Discuss the requirements of chickens for: (a) Calcium; (b) phosphorus; (c) salt; (d) manganese; (e) iodine.
15. Of what importance is grit for poultry?
16. Is it advantageous to add charcoal to poultry rations?
17. Discuss the requirements of poultry for vitamin A and carotene.
18. What is the effect of feed on the color of egg yolks and body tissues?
19. Discuss the vitamin D requirements of poultry, stating the form of vitamin D that is used efficiently by poultry.
20. Which of the B-complex vitamins is most important in feeding poultry? What supplements are used to supply this vitamin for poultry not on good pasture?
21. Discuss: (a) Niacin; (b) vitamin B_{12}; (c) other B-complex vitamins.
22. Is it generally beneficial to add yeast to poultry rations containing an ample supply of B-complex vitamins?
23. What disease is caused by an experimental ration deficient in vitamin E?
24. Discuss the importance of vitamin K for poultry.
25. Name 4 unidentified vitamins or factors that are needed by poultry and state a feed that supplies each of these.
26. Discuss the importance of net-energy values, or productive-energy values in poultry feeding.
27. What is meant by Calorie-protein ratio?
28. What advantages do metabolizable-energy values have over productive-energy values?
29. Discuss high-energy rations for: (a) Chicks and broilers; (b) layers.
30. Discuss antibiotic feed supplements in rations for: (a) Chicks and broilers; (b) hens or growing pullets.
31. What effects have generally been produced by adding an arsonic supplement to a ration for chicks or poults?
32. Have surfactant additions to poultry rations usually been beneficial?
33. How should water be supplied poultry?
34. Discuss the preparation of grain for poultry.
35. What is the chief advantage of pelleted feed for poultry? What is the disadvantage?
36. What different methods of feeding are used for laying hens?
37. Discuss the results from pasture versus confinement or bare range for poultry.
38. What are the best pastures for poultry in your region?
39. Why is it important to follow a careful pasture rotation system for poultry?
40. Discuss the use of alfalfa hay in poultry rations. What substitutes can be used instead of alfalfa?
41. To what extent are fresh green feeds used for poultry in your region?
42. What kind of silage may be useful for poultry?
43. Discuss the requirements of poultry for shelter.
44. What is the effect of very hot weather on chickens? How can these effects be reduced?

45. What kinds of litter are used for poultry in your region? Describe the method of using built-up litter.
46. Describe the structure of an egg.

REFERENCES

1. Winter and Funk, Poultry Science and Practice, Rev. Ed., 1946.
2. Crops and Markets, U.S.D.A., 1955 Ed., Volume 32.
3. Johnson, Del. Pamphlet 14; Young, Ind. Bul. 441; Perry and Dow, Me. Bul. 441; Greene and James, N.C. Research and Farming, 4, 1945, No. 1; Charles, Penn. Bul. 216; Tex. Rpt. 1944.
4. Earle, N.Y., Cornell Feed Service, No. 39.
5. Md. Station, Feedstuffs, March 24, 1956.
6. Dukes, The Physiology of Domestic Animals, 7th Ed., 1955.
7. Heuser, N.Y., Poultry Sci., 24, 1945, pp. 20–24.
8. Bird, Almquist, Cravens, Hill, and McGinnis, Nutrient Requirements for Poultry, National Res. Council, Publication 301, revised, 1954.
9. Matterson, Potter, Stinson, and Singsen, Conn., Poultry Sci., 34, 1955, p. 36; Heuser, Norris, Scott, and Hill, N.Y. (Cornell) Rpt. 1950; Leong, Sunde, Bird, and Elvehjem, Wis., Poultry Sci., 34, 1955, pp. 32–33.
10. Smith, Ark. Bul. 529; Stephenson, Ark. Farm Res., 3, 1954, No. 4; Almquist and Asmundson, Cal., Poultry Sci., 23, 1944, pp. 67–71; Peterson, Grau, and Peek, Cal., Poultry Sci., 31, 1952, p. 931; Matterson, Potter, Stinson, and Singsen, Conn., Poultry Sci., 34, 1955, p. 36; Hoffman and Tomhave, Del. Bul. 425; Mehrhof, O'Steen, and Perry, Fla. Rpt. 1949; Roberts and Carrick, Ind. Bul. 425; Md. Bul. A-78; Miss. Rpt. 66; Irwin and Kempster, Mo. Bul. 441; Ackerson, Blish, and Mussehl, Nebr. Res. Bul. 108; Tepper et al., N.H. Bul. 335; Heuser, Norris, Scott, and Hill, N.Y. (Cornell) Rpts. 1949, 1950; Heller and Penquite, Okla., Poultry Sci., 24, 1945, pp. 465–468; Sherwood, Couch, and Fuller, Texas Rpts. 1940, 1941, 1944; Melass and Sherwood, Texas Rpt. 1943; Carver, Heiman, Cook, and St.John, Wash. Bul. 383; Bearse and Berg, Wash. Bul. 455; Halpin and Holmes, Wis. Bul. 451; Leong, Sunde, Bird, and Elvehjem, Wis., Poultry Sci., 34, 1955, pp. 32–33; Menge, U.S.D.A., Feed Age, Jan. 1954; Slinger, Bergey, Pepper, and Arthur, Canada, Poultry Sci., 30, 1951, p. 936.
11. Hill and Anderson, N.Y., Proc. 1955 Cornell Nutr. Conf.; see also: Ringrose, Potter, and Hatch, N.H., Poultry Sci., 33, 1955, p. 1078; Heuser, N.Y., Poultry Sci., 20, 1941, pp. 362–368; Penquite, Okla. Rpt. 1938–40; Reid, Quisenberry, and Couch, Texas, Poultry Sci., 30, 1951, pp. 935–936; Heiman, Carver, and St.John, Wash. Bul. 331; Clark, Runnels, Rietz, and Weakley, West Va. Bul. 331; Hendricks, U.S.D.A., Poultry Sci., 13, 1934, pp. 290–294; Heywang, Bird, and Varrick, U.S.D.A., Poultry Sci., 34, 1955, pp. 148–152.
12. Duckworth, Scotland, Proc. Nutr. Soc. of Great Britain, 13, 1954, p. 33.
13. For detailed summaries of the nutrient requirements of poultry, see: Ewing, Poultry Nutrition, 4th Ed., 1951; Heuser, Feeding Poultry, 2nd Ed., 1955; Titus, Scientific Feeding of Chickens, 2nd Ed., 1955.
14. Many formulas of mashes for the various classes of chickens are given in Heuser, Feeding Poultry, 2nd Ed., 1955; Titus, The Scientific Feeding of Chickens, 2nd Ed., 1955.
15. Wixom, Pippin, and Day, Ark., Jour. Nutr., 56, 1955, pp. 409–420; Fisher, Scott, and Johnson, Ill., Poultry Sci., 33, 1954, p. 1054; Griminger, Forbes, and Scott, Ill., Poultry Sci., 33, 1954, p. 1057; Snyder, Morrison, and Scott, Ill., Poultry Sci., 33, 1954, p. 1082; Savage, Craghead, O'Dell, and Hogan, Mo., Poultry Sci., 34, 1955, p. 45; Hill, N.Y., Proc. 1953 Cornell Nutr. Conf.; Machlin, U.S.D.A., Poultry Sci., 34, 1955, pp. 984–985; see also: the review by Almquist, Poultry Sci., 31, 1952, pp. 966–981.
16. Ingram, Cravens, Elvehjem, and Halpin, Wis. Bul. 492.
17. Stephenson, Ark., Poultry Sci., 33, 1954, p. 1083; Richardson and Blaylock, Texas, Jour. Nutr., 40, 1950, pp. 169–176; Richardson, Blaylock, and Lyman, Texas, Jour. Nutr., 51, 1953, pp. 515–522; Heywang and Bird, U.S.D.A., Poultry Sci., 29, 1950, pp. 486–495; Machlin, Denton, and Bird, U.S.D.A., Poultry Sci., 31, 1952, pp. 110–114; March, Biely, and Tonzetick, Canada, Jour. Nutr., 42, 1950, pp. 565–575.
18. N.D. Bul. 387.
19. Anderson and Draper, Utah, Poultry Sci., 34, 1955, p. 2.
20. Matterson et al., Conn. and Del. Stations and E. I. DuPont de Nemours and Co., Poultry Sci., 32, 1953, pp. 817–826; Mishler, Carrick and Hauge, Ind., Poultry Sci., 28, 1949, pp. 24–30; Combs, Md., Feed Age, October 1953; Md. Bul. A-78; Ringrose et al., N.H., Poultry Sci., 34, 1955, p. 44; Norris, N.Y., 7th Distillers Feed Conf., 1952; N.D. Bul. 387; Patrick, Tenn., Poultry Sci., 31, 1952, pp. 1075–1077; Reed, Quisenberry, and Couch, Texas, Poultry Sci., 33, 1954, pp. 41–47; Saxena and McGinnis, Wash. Stas. Cir. 197; Menge, Denton, Bird, and Combs, U.S.D.A. and Md., Poultry Sci., 32, 1953, pp. 827–836; Slinger, Pepper, and Hill, Canada, Poultry Sci., 32, 1953, pp. 573–575; see, however: Stephenson, Ark., Poultry Sci., 33, 1954, p. 1083; Combs, Twining, and Laurent, Md. Misc. Pub. 148; Ringrose, Potter, and Hatch, N.H. Bul. 409; Bolin and Bryant, N.D. Bul. 365; Smith, R.I. Res. Quar. Review, 4, 1953, No. 1; Sunde, Waibel, Cravens, and Elvehjem, Wis., Poultry Sci., 30, 1951, pp. 668–671; Titus, Brunbaugh and Mehring, Poultry Sci., 34, 1955, pp. 167–177.
21. Carver and Johnson, Iowa, Poultry Sci., 32, 1953, pp. 701–705; 33, 1954, pp. 543–548; Reiser, Texas, Jour. Nutr., 42, 1950, pp. 319–323; Briggs and Fox, Nat. Institute of Health, Poultry Sci., 34, 1955, p. 57.
22. Reiser, Texas, Jour. Nutr., 44, 1951, pp. 159–175.
23. Carrick, Hauge, Roberts, and Whitson, Ind. Rpt. 1940; Russell, Taylor, and Polskin, N.J., Jour. Nutr., 19, 1940, pp. 555–562.
24. Culton, Upp, and Davis, La. Rpt. 1942.
25. Taylor, Jeffrey, and Russell, N.J., Poultry Sci., 23, 1944, pp. 155–157; Russell, Taylor, Walker, and Polskin, N.J., Jour. Nutr., 24, 1942, pp. 199–211; see also: Walker, Taylor, and Russell, N.J., Poultry Sci., 30, 1951, pp. 525–530.

26. Heywang, U.S.D.A., Poultry Sci., 22, 1943, pp. 446–450.
27. Culton, Upp, and Davis, La. Rpt. 1942.
28. Runnels, Del., Poultry Sci., 34, 1955, pp. 140–144; Lewis et al., Kan., Poultry Sci., 34, 1955, p. 33; Donaldson, Combs, and Romoser, Md., Poultry Sci., 33, 1954, p. 1053; Combs, Md., Better Farming, February, 1955; Waibel, Minn., Poultry Sci., 34, 1955, p. 52; Yacowitz and Chamberlin, Ohio, Poultry Sci., 33, 1954, p. 1090; Sunde and Bird, Wis. Bul. 511; Sunde, Wis., Poultry Sci., 33, 1954, p. 1084; McNally, U.S.D.A., Poultry Sci., 33, 1954, p. 1071; Slinger, McConachie, and Pepper, Canada, Poultry Sci., 34, 1955, pp. 789–793; Biely and March, Canada, Poultry Sci., 33, 1954, pp. 1220–1227; Aitken, Lindblad, and Hunsaker, Canada, Poultry Sci., 33, 1954, p. 1038; Rosenberg, E. I. DuPont de Nemours and Co., Del., and Wis., Poultry Sci., 34, 1955, pp. 1308–1313; Siedler, Scheid, and Schweigert, Amer. Meat Inst. and Univ. of Chicago, Poultry Sci., 34, 1955, pp. 411–414; Carver, Rice, Gray, and Mone, Swift and Co., Poultry Sci., 34, 1955, pp. 544–546; see also: Carrick, Hauge, Roberts, and Whitson, Ind. Rpts. 1939, 1940; Henderson and Irwin, Iowa, Poultry Sci., 19, 1940, pp. 389–395; Pepper, Slinger, and Snyder, Canada, Poultry Sci., 32, 1953, pp. 1084–1085.
29. Hill, Anderson, and Dansky, N.Y., Proc. 1954 Cornell Nutr. Conf.; see also: Buckner, Insko, Henry, and Wachs, Ky. Bul. 495; N.J. Rpt. 1939.
30. Heuser, Feeding Poultry, 2nd Ed., 1955.
31. Bolton, Scotland, British Jour. Nutr., 3, 1949, p. 275.
32. Kennard and Chamberlin, Ohio Bul. 659.
33. Morgan, Mitchell, Ringrose, and Lease, S.C., Poultry Sci., 21, 1942, pp. 212–215.
34. Titus, Byerly, Ellis, and Nestler, U.S.D.A., Poultry Sci., 16, 1937, pp. 118–128; Gutowska and Parkhurst, Mass., Poultry Sci., 21, 1942, pp. 321–328.
35. Clark, Hyre, Weakley, and VanLandingham, West Va. Bul. 345; MacIntyre and Jenkins, Canada, Sci. Agr., 32, 1952, pp. 645–650.
36. Smith, Winget, and Blackard, Cal., Poultry Sci., 33, 1954, pp. 908–919; Singsen, Matterson, and Kozeff, Conn., Poultry Sci., 29, 1950, pp. 635–639; Driggers, Shirley, Davis, and Mehrhof, Fla., Poultry Sci., 30, 1951, pp. 199–204; Shirley et al., Fla., Poultry Sci., 30, 1951, pp. 730–734; 31, 1952, pp. 316–320; 33, 1954, pp. 932–936; Clegg, Hein, Suelter, and McFarland, Kan., Poultry Sci., 33, 1954, p. 1049; Patrick and Schweitzer, Tenn., Poultry Sci., 31, 1952, pp. 888–892; 32, 1953, p. 920; 33, 1954, pp. 1199–1201; Randles, Tenn., Poultry Sci., 33, 1954, p. 1077; Spinks, Berlie, and O'Neil, Canada, Science, 110, 1949, pp. 332–333.
37. O'Rourke, Phillips, and Cravens, Wis., Poultry Sci., 34, 1955, pp. 47–54; see also: Fisher, Singsen, and Matterson, Conn., Poultry Sci., 32, 1953, pp. 749–754.
38. Gillis, Norris, and Heuser, N.Y., Poultry Sci., 32, 1953, pp. 977–984.
39. Gillis, Norris, and Heuser, N.Y., Jour. Nutr., 1954, pp. 115–125; Wilcox, Carlson, Kohlmeyer, and Gastler, S.D., Poultry Sci., 34, 1955, pp. 54–55; Motzok, Arthur, and Branion, Canada, Poultry Sci., 33, 1954, p. 1073; see also: Gerry, Carrick, Roberts, and Hauge, Ind., Poultry Sci., 28, 1949, pp. 19–23.
40. Heuser, N.Y., Poultry Sci., 31, 1952, pp. 85–88; Heuser, N.Y., Proc. 1950 Cornell Nutr. Conf.; see also: Burns, Cravens, Phillips, and Halpin, Wis., Poultry Sci., 29, 1950, p. 752; Burns, Cravens, and Phillips, Wis., mimeo. rpt.
41. Murphy, Penn. Bul. 488; Foss, N.D. Bimo. Bul., 4, 1941, No. 1.
42. Creek et al., Ind., Poultry Sci., 33, 1954, p. 1052; see also: Wilgus, Gassner, Patton, and Harshfield, Colo. Tech. Bul. 49.
43. Ewing, Poultry Nutrition, 4th Ed., 1951, p. 598–599.
44. Kennard and Chamberlin, Ohio Farm and Home Res. No. 248; see also: Heuser and Norris, N.Y., Poultry Sci., 25, 1946, pp. 173–179; Penquite and Thompson, Okla. Bul. 244; Utah Buls. 294, 366; Ewing, Poultry Nutrition, 4th Ed., 1951.
45. Romoser, Combs, and Nicholson, Md., Poultry Sci., 33, 1954, p. 1078; Kempster and Funk, Mo. Bul. 370; Tepper, Durgin and Bottorf, N.H. Cir. 56; Dupras, Robinson, and Platt, N.J. Bul. 762; Heuser and Norris, N.Y., Poultry Sci., 25, 1946, p. 195; Kennard and Chamberlin, Ohio Farm and Home Res., No. 248; Cooney, Ore. Cir. 139; Bird, Oleson, Elvehjem, Hart, and Halpin, Wis., Poultry Sci., 16, 1937, pp. 238–242.
46. Heywang, U.S.D.A., Poultry Sci., 31, 1952, pp. 294–301.
47. Mussehl and Ackerson, Nebr. Quar., 1, 1954, No. 4.
48. Heuser, Feeding Poultry, 2nd Ed., 1955, pp. 527–585.
49. Kennard and Chamberlin, Ohio Bimo. Bul. 232.
50. Roberts et al., Ind. Rpts. 1940, 1942; Davidson and Wiant, Mich. Quar. Bul., 24, 1942, No. 3; Mussehl and Yung, Nebr. Bul. 344; Kennard and Chamberlin, Ohio Bimo. Buls. 207, 213; Gledhill and Smith, R.I. Res., 4, 1953, No. 2; Roberts, Wash. Bul. 435; Nestler, U.S.D.A., Jour. Agr. Res., 54, 1937, pp. 571–582.
51. Couch, Fraps, and Sherwood, Tex. Bul. 521.
52. Sunde, Wis. Bul. 511; Sunde, Wis., Poultry Sci., 32, 1953, p. 926.
53. Petersen, Wiese, Milne, and Lampman, Id., Poultry Sci., 32, 1953, pp. 535–542; Fuller, Carrick, and Hauge, Ind., Poultry Sci., 30, 1951, pp. 912–913; Johnson, Iowa, Poultry Sci., 30, 1951, p. 919; Milligan, Arscott, and Combs, Md., Poultry Sci., 31, 1952, pp. 595–603, 830–837; Briggs, Hill, and Giles, Minn., Poultry Sci., 29, 1950, pp. 723–736; Kinder, Mo. Bul. 584; Norris, Miller, and Yacowitz, N.Y., Proc. 1950 Cornell Nutrition Conference; Denton, Kellogg, Sizemore, and Lillie, U.S.D.A., Jour. Nutr., 54, 1954, pp. 571–577.
54. Kempster and Funk, Mo. Bul. 310; Dearstyne and Bollinger, N.C. Tech. Bul. 55; Barton, N.D. Bul. 233; Ore. Bul. 359; R.I. Rpt. 1943; Carver, Wash. Bul. 354; Halpin and Holmes, Wis. Bul. 421.
55. Titus, The Scientific Feeding of Chickens, 2nd Ed., 1955, p. 96.
56. Singsen et al., Conn., Poultry Sci., 32, 1953, pp. 924–925; 33, 1954, pp. 192–201; Singsen, Conn., Feed Age, June, 1954.
57. Howes and Hutt, N.Y., Poultry Sci., 31, 1952, pp. 360–365.
58. Griminger et al., Ill., Poultry Sci., 32, 1953,

p. 902; Anderson et al., West Va., Poultry Sci., 33, 1954, pp. 120–126; Hare, Anderson, Bletner, and Weakley, West Va., Feed Age, Feb., 1954.

59. Combs et al., Md., Poultry Sci., 33, 1954, p. 1050; Scott et al., N.Y., Proc. 1954 Cornell Nutr. Conference.

60. Petersen, Wiese, and Pappenhagen, Id., Poultry Sci., 34, 1955, pp. 673–678; Tamimie, Ill., Poultry Sci., 34, 1955, p. 50; Johnson, Iowa, Poultry Sci., 32, 1953, pp. 930–931; Combs et al., Md., Poultry Sci., 33, 1954, p. 1050; Arscott and Combs, Md., Poultry Sci., 34, 1955, pp. 843–849; Hill and Kelly, N.C., Poultry Sci., 34, 1955, p. 1031; Camp, Cartrite, Quisenberry, and Couch, Texas, Poultry Sci., 34, 1955, pp. 559–565; Atkinson, Ferguson, and Couch, Texas, Poultry Sci., 34, 1955, pp. 855–860; McGinnis et al., Wash., Poultry Sci., 31, 1952, pp. 100–106; Sunde, Cravens, Elvehjem, and Halpin, Wis., Poultry Sci., 29, 1950, pp. 204–207; Lillie, Sizemore, and Bird, U.S.D.A., Poultry Sci., 32, 1953, pp. 855–862; Branion and Hill, Canada, Poultry, Sci., 32, 1953, pp. 151–158; Morimoto, Ariyoshi, and Hoshii, Japan, Poultry Sci., 34, 1955, pp. 1392–1395.

61. Scott, Morrison, and Griminger, Ill., Poultry Sci., 34, 1955, pp. 1446–1447; Reid, Rozacky, and Couch, Texas, Poultry Sci., 34, 1955, p. 43.

62. Stephenson, Dickson, and Barnette, Ark., Poultry Sci., 33, 1954, p. 1083; Fisher, Scott, and Hansen, Ill., Jour. Nutr., 52, 1954, pp. 13–24; Combs et al., Md., Poultry Sci., 33, 1954, p. 1050; Hill, Borchers, Ackerson, and Mussehl, Nebr., Poultry Sci., 32, 1953, pp. 775–779; Scott, N.Y., Poultry Sci., 30, 1951, pp. 293–297; Atkinson, Ferguson, Quisenberry, and Couch, Texas, Poultry Sci., 34, 1955, pp. 730–734; Slinger, Pepper, and Hill, Canada, Poultry Sci., 31, 1952, pp. 187–188; March, Biely, and Touchburn, Canada, Poultry Sci., 34, 1955, pp. 968–971.

63. Combs et al., Md., Poultry Sci., 33, 1954, p. 1050; Camp, Cartrite, Quisenberry, and Couch, Texas, Poultry Sci., 34, 1955, pp. 559–565.

64. Morrison, Scott, and Norris, N.Y., Poultry Sci., 34, 1955, pp. 38, 738–739; Dannenburg, Reid, Rozacky, and Couch, Texas, Poultry Sci., 34, 1955, pp. 1025–1026.

65. Tamimie, Ill., Poultry Sci., 34, 1955, p. 50.

66. Scott, Morrison, and Griminger, Ill., Poultry Sci., 34, 1955, pp. 1446–1447.

67. Ewing, Poultry Nutrition, 4th Edition, 1951; Heuser, Feeding Poultry, 2nd Ed., 1955; Titus, Scientific Feeding of Chickens, 2nd Ed., 1955.

68. Fraps, Texas Bul. 678; see also: Fraps and Carlyle, Texas Bul. 625.

69. Titus, The Scientific Feeding of Chickens, 2nd Ed., 1955, pp. 247–267.

70. Combs, Md., Feedstuffs, July 16, 1955.

71. Hill and Anderson, N.Y., Poultry Sci., 34, 1955, p. 27; Anderson and Hill, N.Y., Poultry Sci., 34, 1955, p. 2.

72. Singsen and Matterson, Conn. (Storrs) Sta., Mimeo. Prog. Rpt., 1949.

73. Colo. Rpt. 1948; Fransen, Andrews, and Carrick, Ind., Poultry Sci., 34, 1955, pp. 205–209; Kan. Rpt. 1948–50; Williams and Upp, La. Rpt. 1949; Gerry, Maine Bul. 523; Kinder and Strothman, Mo. Bul. 535; Ringrose, N.H. Bul. 376; Ohio Bul. 725; Okla. Cir. C-134; Woodward, Boucher, and Murphy, Penn. Sci. for the Farmer, March, 1949; Patrick, Tenn. Farm and Home Sci., Prog. Rpt. 4; Pepper, Slinger, and Snyder, Canada, Poultry Sci., 32, 1953, pp. 920–921.

74. Singsen, Matterson, and Kozeff, Conn., Poultry Sci., 29, 1950, pp. 779–780; Gerry, Maine Bul. 523; Ringrose, Potter, and Hatch, N.H. Bul. 409; Hill, Anderson, and Dansky, N.Y., Poultry Sci., 35, 1956, pp. 58–59; Okla. Farm Res. Flashes, Nov., 1953; Skinner and Quisenberry, Texas, Poultry Sci., 29, 1950, p. 780.

75. Hill, Anderson, and Dansky, N.Y., Poultry Sci., 35, 1956, pp. 58–59.

76. Singsen, Matterson, Kozeff, and Stinson, Conn., Poultry Sci., 33, 1954, p. 1081; Kan. Rpt. 1950–52; Gerry, Maine Bul. 523; see also: Bearse, Berg, and Miller, Wash., Poultry Sci., 29, 1950, p. 748.

77. Tomhave, Del. Bul. 299; Ky. Rpts. 1947, 1948, 1949, 1951, 1952.

78. Peterson, Grau, and Peck, Cal., Jour. Nutr., 52, 1954, pp. 241–257; Lepp, Harper, and Elvehjem, Wis., Poultry Sci., 28, 1949, pp. 372–374.

79. Hill and Dansky, N.Y., Poultry Sci., 33, 1954, pp. 112–119; Anderson and Hill, N.Y., Poultry Sci., 33, 1954, p. 1038; see also: Panda and Combs, Md., Poultry Sci., 29, 1950, pp. 774–775; Donaldson, Combs, Romoser, and Supplee, Md., Poultry Sci., 34, 1955, p. 16; Heuser, N.Y., Proc. 1949 Cornell Nutr. Conf.; Lillie, Haynes, and Bird, U.S.D.A., Poultry Sci., 30, 1951, p. 922.

80. For reviews of the investigations on antibiotic feed supplements, see: Jukes, Antibiotics in Nutrition, 1955; Stokstad, Antibiotics in Animal Nutrition, Physiological Reviews, 34, 1954, pp. 25–51; Heuser, Feeding Poultry, 2nd Ed., 1955, pp. 47–50.

81. Fell and Stephenson, Ark., Poultry Sci., 32, 1953, pp. 1092–1093; Matterson and Singsen, Conn. (Storrs) Bul. 275; Driggers and Mehrhof, Fla. Rpt. 1950; Rosenberg, Morikawa, and Bushnell, Hawaii, Poultry Sci., 31, 1952, pp. 708–714; Palafox and Rosenberg, Hawaii, Poultry Sci., 31, 1952, pp. 1110–1111; Petersen, Lampman, and Wiese, Id. Bul. 725; Scott, Glista, and Goffi, Ill., Poultry Sci., 30, 1950, p. 930; Nordskog and Johnson, Iowa, Poultry Sci., 32, 1953, pp. 1046–1051; Jones and Combs, Poultry Sci., 32, 1953, pp. 873–875; Ackerson, Borchers, and Mussehl, Poultry Sci., 31, 1952, pp. 1023–1026; Heuser, N.Y., Cornell Feed Service, March, 1951; Heuser, N.Y., Proc. 1951 Cornell Nutr. Conf.; Hill and Kelly, N.C., Poultry Sci., 33, 1954, pp. 687–688; Boucher et al., Penn. Bul. 553; Wisman, Boucher, and Callenbach, Penn., Poultry Sci., 33, 1954, pp. 328–332; Couch and Reed, Texas Prog. Rpt. 1251; Draper, Utah Farm and Home Sci., 12, 1951, No. 3; Burgess, Gluck, and Laughland, Canada, Poultry Sci., 32, 1953, pp. 444–449; Hauser, Anderson, Pepper, and Slinger, Canada, Poultry Sci., 33, 1954, p. 1058.

82. Nelson and Scott, Ill., Poultry Sci., 32, 1953, pp. 601–604; Morrison, Hamilton, and Scott, Ill., Poultry Sci., 34, 1955, pp. 78–81; Eisenstark and Sanford, Kan., Poultry Sci., 32, 1953, pp. 837–839; Todd, Wyant, and Elam, Ky., Poultry Sci., 30, 1951, pp. 818–819; Romoser, Short, and Combs, Md., Poul-

try Sci., 31, 1952, p. 932; Sieburth, Jezeski, Hill, and Carpenter, Minn., Poultry Sci., 33, 1954, pp. 753–762; West and Hill, Miss. Farm Res., 16, 1953, No. 6; 17, 1954, No. 6; Thayer and Heller, Okla., Poultry Sci., 34, 1955, pp. 97–102; Elam et al., Texas, Poultry Sci., 31, 1952, pp. 914–915; McGinnis, Wash., Proc. 1950 Cornell Nutr. Conf.; Monson et al., Wis., Jour. Nutr., 52, 1954, pp. 627–636; Biely and March, Canada, Science, 114, 1951, pp. 330–331; Biely and March, Canada, Poultry Sci., 31, 1952, pp. 177–179.

83. Runnels, Reynolds, and Waller, Del., Poultry Sci., 30, 1951, pp. 929–930; Davis and Briggs, Minn., Poultry Sci., 30, 1951, pp. 767–771; Wisman, Boucher, and Callenbach, Penn., Poultry Sci., 33, 1954, pp. 290–293; Kramke and Fritz, Poultry Sci., 30, 1951, p. 921; Titus, Scientific Feeding of Chickens, 2nd Ed., 1955, p. 280; Jukes, Antibiotics in Nutrition, 1955, p. 58; see, however, Morgan and Willimon, S.C. Rpt. 64; McGinnis et al., Wash., Poultry Sci., 29, 1950, p. 771.

84. Libby and Schaibel, Mich., Science, 121, 1955, pp. 733–734; Carlson, S.D. Farm and Home Res., 5, 1954, No. 2; Waibel, Abbott, Baumann, and Bird, Wis., Poultry Sci., 33, 1954, pp. 1141–1146.

85. Hill and Kelly, N.C., Jour. Nutr., 51, 1953, pp. 463–466; Lillie, Sizemore, and Bird, U.S.D.A., Poultry Sci., 32, 1953, pp. 466–475; Hill, Branion, Slinger, and Anderson, Canada, Poultry Sci., 32, 1953, pp. 462–466; Morrison, Hunsaker, and Aitken, Canada, Poultry Sci., 33, 1954, pp. 491–494.

86. Matterson, Singsen, Decker, and Kozeff, Conn., Poultry Sci., 31, 1952, p. 926; Miss. Rpt. 66; Saxena, Berg, and McGinnis, Wash., Poultry Sci., 31, 1952, pp. 1070–1074; Waibel, Cravens, and Baumann, Wis., Jour. Nutr., 50, 1953, pp. 441–450; see also: Sanford, Kan., Poultry Sci., 31, 1952, pp. 933–934.

87. Titus, Scientific Feeding of Chickens, 2nd Ed., 1955, p. 280.

88. Moreng, Bolin, Bryant, and Gosslee, N.D. Bul. 398; Branion, Hill, and Motzok, Canada, Poultry Sci., 31, 1952, pp. 1096–1098.

89. Peterson and Lampman, Id., Poultry Sci., 31, 1952, pp. 1067–1069; Carlson and Kohlmeyer, S.D., Poultry Sci., 33, 1954, p. 1047; Draper, Utah Farm and Home Sci., 12, 1951, No. 3; Carver, McGinnis, Berg, and Bearse, Wash., Poultry Sci., 30, 1951, pp. 909–910; Sunde, Halpin, and Cravens, Wis., Poultry Sci., 31, 1952, pp. 617–620; Sunde and Cravens, Wis., Poultry Sci., 31, 1952, pp. 621–624; Lillie and Bird, U.S.D.A., Poultry Sci., 31, 1952, pp. 513–518; Sizemore, Lillie, Denton, and Bird, U.S.D.A., Poultry Sci., 32, 1953, pp. 618–624; Brown, Robblee, and Clandinin, Canada, Poultry Sci., 32, 1953, pp. 576–578; Sherwood and Milby, Poultry Sci., 33, 1954, pp. 1031–1033; see however: Kennard and Chamberlin, Ohio Bul. 725; Carlson and Kohlmeyer, S.D., Poultry Sci., 33, 1954, p. 1047; Heywang, U.S.D.A., Poultry Sci., 33, 1954, p. 1059.

90. Elam, Jacobs, and Couch, Texas, Poultry Sci., 32, 1953, pp. 792–793; Lillie and Sizemore, U.S.D.A., Poultry Sci., 33, 1954, pp. 427–429.

91. Balloun, Iowa, Poultry Sci., 33, 1944, p. 869.

92. Sizemore, Lillie, Denton, and Bird, U.S.D.A., Poultry Sci., 32, 1953, pp. 618–624.

93. Bentley and Hershberger, Ohio, Poultry Sci., 33, 1954, pp. 641–648; Slinger, Ferguson, and McConachie, Canada, Poultry Sci., 21, 1952, pp. 172–174.

94. Libby, Evans, Bandemer, and Schaible, Mich., Poultry Sci., 34, 1955, pp. 972–980; Combs, Romoser, and Bishop, Md., Jour. Nutr., 53, 1954, pp. 511–521; Md. Bul. A-78; Tarver, Patrick, and Goff, Tenn., Poultry Sci., 33, 1954, p. 1085; Bird, Groschke, and Rubin, U.S.D.A., Jour. Nutr., 37, 1949, pp. 215–225; Bird, U.S.D.A., Feed Age, Sept., 1952; Morrison, Hunsaker, and Aitken, Canada, Poultry Sci., 33, 1954, pp. 491–494; Anderson, Cunningham, and Slinger, Canada, Jour. Nutr., 48, 1952, pp. 539–552; Morehouse, Poultry Sci., 28, 1949, pp. 375–384; Milligan et al., Poultry Sci., 34, 1955, pp. 794–798; see, however: Scott and Glista, Ill., Poultry Sci., 29, 1950, pp. 921–923.

95. Abbott, Bird, and Cravens, Wis., Poultry Sci., 33, 1954, pp. 1245–1253; see also: Morrison, Hunsaker, and Aitken, Canada, Poultry Sci., 33, 1954, pp. 491–494.

96. Libby, Groschke, Evans, and Bandemer, Mich. Quar. Bul. 35, 1953, No. 4; Libby, Evans, Bandemer, and Schaible, Mich., Poultry Sci., 34, 1955, pp. 972–980; Pepper, Slinger, and Bergey, Canada, Poultry Sci., 33, 1954, pp. 422–423; Morehouse, Poultry Sci., 28, 1949, pp. 375–384; 33, 1954, p. 1072; Wharton and Fritz, Poultry Sci., 32, 1953, pp. 1014–1020.

97. Scott, Johnson, and Goffi, Ill., Poultry Sci., 31, 1952, pp. 746–747; Snyder, Johnson, and Scott, Ill., Poultry Sci., 32, 1953, pp. 527–531; Stern and McGinnis, Wash., Poultry Sci., 32, 1953, pp. 26–28; Branion and Hill, Canada, Poultry Sci., 33, 1954, pp. 62–66; March, Burdett, and Biely, Canada, Poultry Sci., 33, 1954, pp. 300–304; Morrison, Hunsaker, and Aitken, Canada, Poultry Sci., 33, 1954, pp. 491–494; see also: Ely, Science, 114, 1951, pp. 523–524; Ely and Schott, 7th Distillers Feed Conf., 1952.

98. Balloun, Iowa, Poultry Sci., 34, 1955, pp. 191–196; Md. Bul. A-74; Ney and Newell, Poultry Sci., 33, 1954, pp. 297–299.

99. Hood, Wheeler, and McGlamery, Ga., Poultry Sci., 29, 1950, pp. 824–828; Detweiler, Andrews, and Bohren, Ind., Poultry Sci., 29, 1950, pp. 513–519; Payne, Kan. Rpt. 1946–48; Herrick and Brown, Kan., Poultry Sci., 31, 1952, pp. 191–193; Md. Bul. A-53; Moreng, Jacobson, and Bryant, N.D. Bimo. Bul., 14, 1952, No. 4; Moreng and Bryant, N.D. Bimo. Bul., 15, 1953, No. 6; Stadelman, Wash., Poultry Sci., 31, 1952, pp. 310–315; Adams, Wis. Bul. 498; see also: Heuser, Feeding Poultry, 2nd Ed., 1955, pp. 448–450.

100. Akpinar and Shaffner, Md., Poultry Sci., 32, 1953, pp. 119–122.

101. Godfrey and Jaap, Ohio, Poultry Sci., 29, 1950, pp. 356–361.

102. Ariz. Rpts. 1948, 1949, 1951; Wilson, Cal., Poultry Sci., 28, 1949, pp. 581–592; Davis, Mehrhof, and Driggers, Fla. Rpt. 1946; Winchester, Comar, and Davis, Fla. Rpt. 1949; Ky. Rpt. 1948; Glazener, Shaffner, and Jull, Md., Poultry Sci., 28, 1949, pp. 834–849; McCartney and Shaffner, Md., Poultry Sci., 29, 1950, pp. 67–77; Savage, Turner, Kempster, and Hogan, Mo., Poultry Sci., 31, 1952, pp. 22–31; Maghrabi and Turner, Mo. Res. Bul. 523; Ackerson, Borchers, Temper, and Mussehl, Nebr. Rpt.

63; Godfrey, Okla., Poultry Sci., 28, 1949, pp. 867–873; Berg and Bearse, Wash., Poultry Sci., 30, 1951, pp. 21–28; Lillie, Sizemore, Milligan, and Bird, U.S.D.A., Poultry Sci., 31, 1952, pp. 1037–1042; Freedeen, Canada, Poultry Sci., 32, 1953, p. 900; Oloufa, Egypt, Poultry Sci., 32, 1953, p. 391; 33, 1954, pp. 649–652.

103. Beresford, Id., Agr. Engin., 11, 1930, No. 8, Kaible and Fox, Ore. Cir. 81.

104. James and Wheeler, Ga., Poultry Sci., 28, 1949, pp. 465–467.

105. Kennard and Chamberlin, Ohio Bul. 725.

106. Heywang, U.S.D.A., Poultry Sci., 20, 1941, pp. 184–187; Ewing, Poultry Nutrition, 4th Ed., 1951; Heuser, Feeding Poultry, 2nd Ed., 1955.

107. Kennard and Nettleton, Ohio Bimo. Bul. 128; Alder, Utah Farm and Home Sci., 2, 1941, No. 2; see also: MacIntyre and Jenkins, Can. Jour. of Agr. Sci., 34, 1954, pp. 10–17.

108. Poley, Ind., Poultry Sci., 17, 1938, p. 331.

109. Peterson and Zweigart, Cal. Agr., 8, 1954, No. 3; Lindblad, Aitken, and Hunsaker, Canada, Poultry Sci., 34, 1955, p. 34.

110. For reviews of the experiments with pellets or crumbles, see: Ewing, Poultry Nutrition, 4th Ed., 1951; Heuser, Feeding Poultry, 2nd Ed., 1955.

111. Himmers, Ill., Feed Age, March, 1954; Stewart and Upp, La., Poultry Sci., 30, 1951, pp. 63–66; Smyth, Gerry, and Howes, Maine Bul. 473; Lanson, Maine Farm Res., 2, 1954, Nos. 1, 4; Lanson and Smyth, Maine, Poultry Sci., 34, 1955, pp. 234–235; Mussehl, Ackerson, and Borchers, Nebr. Rpt. 63; Ringrose, N.H. Bul. 382; Ore. Bul. 477; Bearse, Berg, McClary, and Miller, Wash., Poultry Sci., 31, 1952, p. 907; Wyo. Rpts. 57, 59.

112. Smyth, Gerry, and Howes, Maine Bul. 473; Hill, Anderson, and Dansky, N.Y., Proc. 1954 Cornell Nutr. Conf.; Berg and Bearse, Wash. Bul. 522; Jensen and McGinnis, Wash., Poultry Sci., 31, 1952, pp. 307–310; Anderson and MacGregor, Canada, Sci. Agr., 32, 1952, pp. 677–679.

113. Hinds, Ariz. Bul. 184; Skoglund and Watkins, Del. Bul. 238; Hoffman, Del. Bul. 254; Payne and Gish, Kan. Bul. 320; Vondell, Mass., U.S. Egg and Poultry Mag., 49, 1943, pp. 464–466; Davidson, Rather, and Card, Mich. Quar. Bul. 25, 1943, No. 4; Heuser, Norris, and Bruckner, N.Y. (Cornell) Bul. 823; Kennard and Chamberlin, Ohio Bimo. Buls. 209, 215, 223, 228; Kennard, Thatcher, and Chamberlin, Ohio Farm and Home Res. No. 251; Parker and McSpadden, Tenn. Bul. 188; Stephenson and Bryant, Va. Bul. 362; Henderson, Whelden, and Wood, Vt. Bul. 568; Cunningham and Clark, West Va. Bul. 317.

114. King, Ala. Rpt. 1944; Skoglund, Tomhave, and Kish, Del. Bul. 266; Mehrhof and Killinger, Fla. Rpt. 1949; Carrick, Ind. Rpts. 1937, 1943; Payne and Gish, Kan. Bul. 320; Tower and Upp, La Rpt. 1944; Sipe and Polk, Miss., Poultry Sci., 20, 1941, pp. 406–412; Berry, N. Mex. Bul. 255; Winter, Chamberlin, Burkhart, and Kennard, Ohio Farm and Home Res. No. 277; Parker and McSpadden, Tenn. Bul. 185; Godfrey and Titus, U.S.D.A., Poultry Sci., 13, 1934, pp. 56–60.

115. Hoffman, Del. Bul. 254; N.J. Cir. 536; Kennard, Thatcher, and Chamberlin, Ohio Farm and Home Res. Nos. 246, 257.

116. Cottier and King, Ala. Rpt. 1940; Miss. Rpt. 1942.

117. Buckner, Insko, and Henry, Ky., Poultry Sci., 24, 1945, pp. 446–450.

118. Heuser, Feeding Poultry, 2nd Ed., 1955, p. 394.

119. For information on the requirements for poultry houses, see: Ashby, Miller, Edick, and Lee, U.S.D.A. Cir. 738; Jones, Funk, Halpin, Jull, and Thompson, N.J. Bul. 732; Cooke, Minn. Exten. Bul. 121.

120. Ota, McNally, and Wilson, Cal. and U.S.D.A., Poultry Sci., 34, 1955, pp. 40–41; Warren. Conrad, Schumacher, and Avery, Kan. Tech. Bul. 68.

121. Wilson et al., Cal., Poultry Sci., 30, 1951, pp. 625–627; 31, 1952, pp. 847–850; 32, 1953, p. 929; see also: Rosenberg and Tanaka, Hawaii, Poultry Sci., 30, 1951, pp. 745–747.

122. Wilson and Hillerman, Cal., Poultry Sci., 31, 1952, pp. 847–850.

123. Seeger, Tomhave, and Lucas, Del. Bul. 289.

124. Kennard and Chamberlin, Ohio Farm and Home Res., Nos. 248, 250, 251, 253, 256, 261, 265, 267, 276; Kennard and Chamberlin, Ohio, Poultry Sci., 29, 1950, p. 766; 30, 1951, pp. 47–54; 34, 1955, pp. 30–31; Bentley, Kennard, and Chamberlin, Ohio Farm and Home Res. No. 274; Winter and Cotterill, Ohio Farm and Home Res., No. 280; Kennard, Moore, and Chamberlin, Ohio, Poultry Sci., 32, 1953, p. 931; Moore and Chamberlin, Ohio Farm and Home Res., No. 282.

125. Lampman and Petersen, Id. Buls. 270, 280; Eggleton, Johnson, Whitfield, and Phillips, Iowa Bul. P-108; Rosenberg and Tanaka, Hawaii Bul. 107; Champagne, Watts, and Upp, La. Rpt. 1951; Miss. Rpt. 66; Halbrook, Winter, and Sutton, Ohio, Science, 112, 1950, pp. 308–309; Halbrook, Winter, and Sutton, Ohio, Poultry Sci., 29, 1950, pp. 672–678; 30, 1951, pp. 381–388; Halbrook, Sutton, and Winter, Ohio, Poultry Sci., 29, 1950, pp. 679–684; Bearse and Berg, Wash. Bul. 455; Miller, Wash. Bul. 470; Sunde, Cravens, and Halpin, Wis., Poultry Sci., 30, 1951, p. 932.

126. Levine, N.Y., Cornell Feed Service, August, 1951.

127. For a detailed discussion of the structure and composition of eggs, see: Romanoff and Romanoff, The Avian Egg, 1949; see also: Taylor, The Fertility and Hatchability of Chicken and Turkey Eggs, 1949.

CHAPTER XXXVII

FEEDING AND CARING FOR POULTRY

I. Feeding and Caring for Laying Hens

1556. Essentials in rations for laying hens.—In order to produce eggs economically, a high rate of egg production must be maintained in a flock of laying hens. To secure this, the hens must be fed a ration which is complete and well-balanced and which meets fully the nutritive requirements that have been discussed in the preceding chapter. It is also essential that the hens eat large quantities of feed. The ration must therefore be palatable and be fed in a manner that stimulates high feed consumption.

Detailed information has been given in the preceding chapter concerning the nutrient requirements of layers. Also, the ways have been explained by which these requirements can be fully met in practical rations. In Appendix Table VII several example rations are presented that are adapted to conditions in various regions.

1557. Grains for poultry.—All of the cereal grains can be used satisfactorily in rations for laying hens and for other poultry. Information about the use and relative value of the different grains for poultry is given in Chapters XX and XXI.

In most parts of the United States corn is the chief grain fed to poultry, and it gives excellent results when used in properly balanced rations. (**705**) Yellow corn aids in meeting the vitamin A requirements, and it also produces yellow color in egg yolks and body tissues. (**1518**) When other grains replace all or much of the yellow corn in a poultry ration, their lack of vitamin A value must be corrected by an ample supply of the vitamin from other sources.

Though oats are considerably lower than corn or wheat in net-energy value for poultry, they are desirable in poultry rations for certain special qualities. (**726**) Because of the oat hulls, including oats in poultry rations tends to prevent feather picking and cannibalism. The hulls also seem to provide a factor that improves growth and feather development in chicks and reduces mortality.

Heavy, plump oats should, if possible, be used for poultry, as light-weight oats have a low value for them. For use in a mash, oats should be ground fine enough to prevent the birds from picking out the kernels and leaving the hulls.

Wheat is liked the best of all the grains by poultry and is equal or slightly superior to corn in value per 100 lbs. (**738**) Though wheat is not at all essential in poultry rations, a limited amount is often fed, even when other grains are cheaper, because of the palatability of wheat and to furnish greater variety. If hens are fed, free-choice, all the wheat they will eat, and also mash, free-choice, they will usually eat a much greater amount of wheat than of mash. It may therefore be necessary to restrict the amount of wheat, in order to get them to eat enough of the mash to balance the ration properly.

Barley is a satisfactory substitute for corn or wheat in poultry rations. (**761**) It is somewhat less palatable than these grains to poultry, but they soon become accustomed to it. Because of the hulls, the feeding value of barley for poultry is appreciably less per pound than that of corn. For this reason, a large proportion of barley cannot be included in high-energy mashes.

The grain sorghums are widely used for poultry in the sorghum-belt, and are nearly equal to corn in value per pound. (**779**) Rice, emmer, hog millet, or buckwheat can also be used in poultry rations. (**783, 788–790**) Hominy feed is a

good substitute for corn in poultry rations. (708)

1558. Wheat by-products.—Wheat by-products are common ingredients of poultry mashes. (753) Because of the popularity of high-energy mashes, wheat bran is fed less than formerly. Instead, wheat middlings and wheat red dog, which are lower in fiber, are used.

The wheat by-products help furnish protein, and supply the vitamin or vitamins that are needed, in addition to manganese, for the prevention of perosis, or slipped tendon, in chicks. Rations containing these feeds also tend to produce more rapid growth and better feathering of growing chickens.

Because wheat bran and wheat standard middlings or brown shorts are considerably lower than grain in net-energy value for poultry, too large a percentage should not be included in poultry rations. The proportions of these feeds that are commonly used are indicated in the example rations in Appendix Table VII.

1559. Protein-rich supplements.—The protein requirements of poultry, both for amount and for quality of protein, have been discussed in the preceding chapter. As stated there, the best results are generally secured when the ration contains at least a small percentage of protein supplements of animal origin, such as dairy by-products, meat scrap, or fish meal. (1500) The advantage from animal-protein supplements is greater for poultry that are confined than for those on good pasture or range. This is due not only to the nutrients in the green forage they eat, but also to the insects and worms they secure, which help supplement their diet.

The desirable proportions of animal-protein supplements in rations for laying hens and for chicks are shown in the preceding chapter. (1501) If there is a shortage of animal-protein supplements, reasonably good egg production can be secured when such supplements are entirely replaced by soybean oil meal. It is then especially necessary to be careful to supply the proper amounts of calcium, phosphorus, and vitamins.

Information is given in Chapters XX to XXIII concerning the values and use of the many different protein supplements.

1560. Mineral, vitamin, and other supplements.—It has been emphasized in the preceding chapter that laying hens have particularly high requirements for calcium, because egg shells are composed almost entirely of this mineral. The most common method of supplying plenty of calcium for layers is to include 1.0 to 2.5 per cent of ground limestone or other calcium supplement in the mash, and also to let the hens have access at all times to oyster shell or limestone grit, fed separately. (1508)

The requirements of laying hens for phosphorus, manganese, iodine, and grit have been considered in the preceding chapter.

Unless laying hens are on first-rate pasture or are fed an abundance of fresh green feed, it is necessary to add vitamin A and riboflavin supplements to the ration. Also, unless the hens have sufficient exposure to sunlight which has not passed through window glass, a vitamin D supplement must be supplied.

Detailed information has been given in the previous chapter concerning the requirements of hens for other vitamins, including vitamin B_{12} and the unidentified vitamins or factors. Also, antibiotic supplements, arsonic supplements, surfactants, and hormones are there discussed.

1561. Amounts of feed required by laying hens.—The amount of feed required daily by hens depends on the rate of egg production, the size of the birds, their age, and the weather. Pullets require somewhat more feed than do mature hens for the same rate of egg production, as they are still growing. More feed is needed in cold weather than at other times.

Approximately the amounts of feed shown in the following table are needed daily by 100 laying hens at various rates of egg production.[1]

(A 30 per cent rate of egg production means that 30 eggs are laid daily per 100 hens.)

The estimates for light breeds are for such breeds as Leghorns, and those for heavy breeds, for such breeds as Rhode Island Reds, New Hampshires, or Plymouth Rocks.

Approximate daily amount of feed for 100 laying hens

Rate of egg production Per cent	Light breeds (av. wt. 4 lbs.) Lbs.	Heavy breeds (av. wt. 5½ lbs.) Lbs.
30	22	25
40	23	26
50	24	27
60	25	28
70	26	29
80	27	30

1562. Methods of feeding laying hens.—In almost all methods of feeding, laying hens are full-fed a mash which contains protein, mineral, and vitamin supplements. Sometimes all or part of the mash is fed in pelleted form. (**1544**)

Except in the all-mash method, the hens are fed grain separately, in addition. Generally, this grain is given in a limited or controlled amount, and fed either as scratch grain in the litter or in the proper amount daily in open hoppers or troughs.

Sometimes the cafeteria, or free-choice, method is used, in which both dry mash and grain are full-fed, separately in hoppers. The hens are allowed to eat as much of each as they wish. Another method is the use of an all-mash ration. In this method the proper proportion of grain (usually ground or cracked) is included in the mash, which is full-fed in hoppers.

Laying hens should not be changed quickly from one method of feeding to another, as this is apt to reduce feed consumption.

1563. Mash-and-scratch-grain method.—A common method of feeding laying hens is the mash-and-scratch-grain method. In this method a laying mash that contains 20 to 23 per cent of protein is full-fed dry in hoppers. In addition, a limited amount of scratch grain is fed by scattering it in the litter, so the birds will get exercise in scratching for it. The scratch grain is commonly a mixture of whole grains, though the corn is sometimes cracked coarsely.

In this method the aim is to have the hens eat approximately equal weights of grain and mash, so that their total ration will have the proper percentage of protein and also sufficient amounts of minerals and vitamins.

The mixture of grain is ordinarily more palatable to the fowls than the mash. Therefore, they will clean the grain up and then eat enough mash to satisfy their appetites. To build up the bodies of the birds or to increase the total feed consumption, the amount of grain should be increased, which automatically reduces the amount of mash eaten. To stimulate egg production, the amount of grain is reduced, so the fowls will eat more of the mash, containing the protein supplements. In cold weather, when there is a greater need for energy and when feed consumption is higher, the proportion of grain may be higher than when it is warmer. At no time should the hens eat more than 2 lbs. of grain for each pound of mash of the usual type.

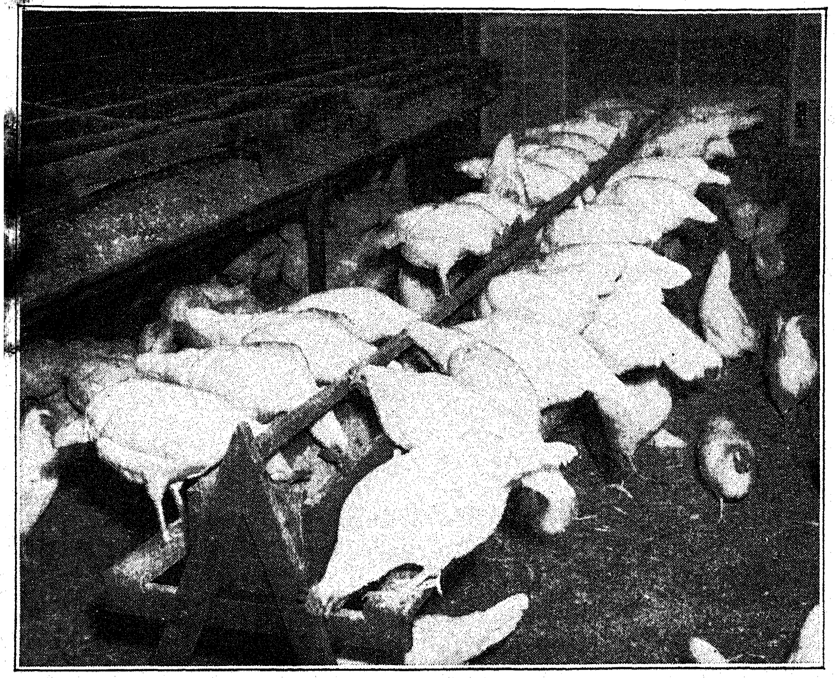
In order to get the hens to eat enough mash, only a light feeding of scratch grain is given in the morning (about one-fourth of the total daily amount). In the late afternoon, the hens are given all the scratch grain they will clean up, so they will go to roost with full crops.

The birds should be examined occasionally after they have gone to roost, to see whether they have had enough grain. At night it is better to feed a little more than will be eaten than not to feed enough. However, the morning feed must be light enough so that the grain will be entirely cleaned out of the litter before the afternoon feeding. During cold weather a small feeding of scratch grain is sometimes given at noon to keep the birds active.

Unless the hens are of an especially well-bred strain, the egg production is apt to be appreciably higher in this method than when grain is full-fed. Another important advantage of the scratch-grain method is that it keeps the litter

loose and dry. Feeding at least some grain in the litter is essential in using "built-up litter." (1554)

A disadvantage of this method is that it requires somewhat more skill and experience on the part of the poultryman than in the free-choice method or the all-mash method.



HENS EATING LAYING MASH FROM A FEED HOPPER

Note the guard above the hopper to prevent the hens from getting into it. (From Ogle, New York State College of Agriculture, Cornell University.)

1564. Mash with limited grain in hoppers.—Instead of feeding scratch grain in the litter, sometimes a limited amount of grain is fed in hoppers or troughs, in addition to the full-feeding of dry mash. The consumption of grain can be regulated in this method, just as in the scratch-grain method.

Generally, the grain is given separate from the mash, but sometimes it is distributed on top of the mash. If disease is present in the flock, it may spread less with this method than when scratch grain is fed in the litter.

When all of the grain is fed in troughs, the litter is apt to become packed down and badly soiled. To prevent this, some grain can be scattered in the litter in the morning.

1565. The free-choice, or cafeteria, method.—In the free-choice, or cafeteria, method, mash is full-fed at all times in open hoppers, or feeders. Grain is also full-fed, free-choice, in separate feeders. The hens are allowed to eat whatever proportion of mash and grain they desire. If more than one kind of grain is fed, the different kinds may be mixed together, or each kind may be supplied in separate feeders. A modification of this method is to feed some of the grain by hand in the litter, so that the birds will work over the litter and keep it loose and dry.

If corn or wheat is full-fed by this method, the hens are apt to eat much more grain than mash. Unless the mash is higher than usual in protein and also

in mineral and vitamin supplements, the ration will be too low in these nutrients. To aid in preventing this, a mash is often used which has 26 per cent or more of protein and also a higher content of mineral and vitamin supplements. Mashes that contain 26 to 30 per cent of protein are often called "supplements" and those containing 32 per cent or more of protein, "concentrates."

This method saves labor, and it is well suited for an inexperienced poultryman. It is better adapted to a flock which has an inherited capacity for high egg production than to a flock which is less well bred. It is also most successful when moist mash is fed in addition to the dry feed, or when the mash is supplemented with liquid or condensed skimmilk or buttermilk, or with pellets.

Several experiments have been conducted with laying hens to compare the free-choice feeding of grain and of mash with the feeding of a limited amount of grain and unlimited mash.[2] In some tests the results have been just as satisfactory with the free-choice method. However, in other trials the egg production has been lower and cannibalism and mortality have been greater with this method than when only a limited amount of grain was fed in addition to mash.

For example, the results have been decidedly better from limited grain feeding of pullets in tests during 7 years at the Ohio Station.[3] It was concluded from these experiments that rather than to full-feed grain separately, it was better to mix the whole grain and mash together in proper proportions, and then full-feed the mixture. This mixture may be fed once or twice daily in the amount that will be eaten before the next feeding period.

1566. Wet mash.—Since the development of modern poultry rations that fully meet the nutritive requirements, the feeding of mash in wet form to laying hens has become much less common than some years ago. Satisfactory feed consumption can generally be secured when a good dry mash is full-fed with grain in addition.

If the hens do not eat the desired amount of dry feed, it may stimulate consumption to feed some of the mash in wet form once or twice a day, supplying only as much as will be entirely cleaned up. However, feeding wet mash requires more labor. In 3 North Dakota experiments with laying pullets, there was no advantage from the regular feeding of wet mash in addition to dry mash and grain.[4]

Often, supplemental wet mash is fed to layers in hot summer weather, in order to keep up feed consumption and to aid in keeping the hens from going into a molt. In 3 Oregon trials with yearling hens, such supplemental feeding of wet mash delayed molting and increased the net returns.[5]

1567. All-mash method.—In the all-mash method of feeding laying hens, a single mash mixture is used, which includes all the grain as well as the supplemental feeds. In addition, the hens may be given free access to a calcium supplement and grit, or the entire amount of calcium supplement needed may be included in the mash.

This method has become much more common in recent years with the use of automatic feeding equipment in large scale poultry enterprises, and with the extensive adoption of laying batteries in some areas. It is used less frequently for layers housed in floor pens.

Except where automatic feeders are used, the mash is fed dry in hoppers, to which the hens have access at all times. The grain is usually all ground, which slightly increases the cost. The mixture should not be too fine, or it will be less palatable. Sometimes whole grain, such as oats, is included in the mash.

An all-mash ration must include the proper proportion of protein and vitamin supplements. Usually such a ration has about half as much of these supplements as a mash for feeding with scratch grain.

If there is considerable trouble from disease in the flock, there may be an advantage in this method, because the feed is not contaminated by the litter, as may occur in the feeding of scratch grain. Also, the color of the egg yolks

can be controlled more uniformly with the all-mash method, because all of the hens must eat the same mixture of feeds.

The all-mash method gives very satisfactory egg production when a high-energy mash is used. If a bulkier mash is fed, containing more fiber, it is difficult to maintain high egg production and keep up the body weights of the birds, especially in cold weather. In recent New York experiments, high egg production and satisfactory maintenance of body weight were secured on a high-energy, all-mash ration in winter, without supplemental feeding of pellets.[6]

In some experiments comparing the all-mash method with feeding whole grain in addition to mash, the results have been just as satisfactory from the all-mash rations, especially with high-energy mashes.[7] In tests with mashes having less productive energy, the egg production has often been appreciably lower with the all-mash method, even when pellets were fed in addition.

A disadvantage of an all-mash ration is that the litter is apt to become packed down and wet. More frequent cleaning of the pens is therefore often needed. Also, there is an added cost for grinding all the grain.

When an all-mash ration is fed in hoppers, fresh feed should be added daily, and the feed should preferably be stirred up several times a day.

1568. Use of artificial light.—Many poultrymen use electric lights to provide additional light in the laying house during the fall and winter, in order to lengthen the hours of light and thus secure more eggs when the price is usually highest. Numerous experiments have been conducted to determine the effects of using artificial light for laying hens.[8]

The experiments have shown that in fall and winter, when the days are short, the egg production is appreciably increased by lengthening the time when it is light. However, the annual egg production is generally not increased, because the hens do not lay so many eggs during the following spring and summer.

It was originally believed that the increase in production thus secured was due to the lengthening of the time during which the hens were able to feed. Investigations have shown, however, that the additional light has a stimulating effect on the pituitary gland and steps up its hormone secretion.[9] (**54**) This increases egg production, even when the hens are not allowed to eat additional feed.

Generally, lights are used for a sufficient period each day to provide, together with the daylight, about 13 to 14 hours of light. In the most common method, the lights are turned on by an automatic clock device some hours before daybreak, and then turned off when daylight comes. This method is about as effective as any. Where electricity is cheap, lights are sometimes used all night.

A 40-watt bulb gives enough light for a pen of 50 to 100 hens. The light should be placed in the center of the pen, over the feeders and waterer. It should have a broad reflector to throw the light toward the floor.

When lights are used, the feeding schedule should be so arranged that the birds will have plenty of feed during the entire time that it is light. For example, when lights are used early in the morning, grain for the morning feeding should be scattered in the litter or be put in the feed hoppers in the evening after the birds have gone to roost. It is important to regulate the feeding so that egg production will not be stimulated so much that the hens run down in condition.

1569. Points in feeding and caring for hens.—The advantages of providing good pasture for poultry have been emphasized in the previous chapter. (**1546**) Wherever it is possible, suitable uncontaminated pasture should be provided for the laying flock. This will not only save feed, but will also make possible the use of a cheaper mash.

The combination of good pasture and exposure to sunlight will largely take care of the vitamin requirements. Also, legume pasture or even young grass pasture helps meet the protein requirements. Therefore, less protein and

vitamin supplements are needed in a mash for hens on good pasture. Furthermore, when hens have free range on first-rate pasture, no protein supplements of animal origin are necessary. The protein supplements can then be entirely soybean oil meal combined with other supplements of plant origin.

When range is provided for the layers during the winter season, it is advisable during wet or rainy weather to keep the flock in the house until one o'clock in the afternoon, in order to reduce the number of dirty eggs. The eggs should be gathered before the fowls are turned out.

Plenty of fresh water should always be provided laying hens. (**1541**) As stated in the preceding chapter, grit should also be supplied. (**1514**)

When laying hens are confined in laying cages or batteries, instead of being housed in the usual manner, special care is necessary to feed a ration that completely meets their nutritive requirements. The all-mash method of feeding is generally used. Fresh feed should be supplied each day, and feeders and water troughs must be kept clean.

In a flock on a general farm it is generally best to use pullets instead of mature hens for egg production. On the other hand, the use of mature hens is highly desirable in constructive breeding.

Pullets generally produce more eggs in a year and more eggs in the fall than do mature hens, but the eggs of pullets are smaller. If not enough good pullets are raised to replace the entire flock, good production can, however, be secured from carefully culled mature hens. In Michigan tests, the egg production per bird and the cost per dozen eggs were about the same for pullets and for selected mature hens.[10]

To save feed and reduce the cost of egg production, it is important to cull the flock carefully not later than March 1. By examining each bird, an experienced poultryman can cull out the non-layers, as well as any birds which are diseased or injured.

1570. Costs in egg production.—Feed is by far the largest item of expense in egg production. The cost of feed will generally be slightly more than one-half of the total gross cost. Man labor is next in importance, forming about one-fourth of the total expense. To the cost of feed and man labor must be added the other expenses, including the charge for the use of buildings, land, and equipment, the cost of chicks or hatching eggs purchased, expense for tractor or horse labor and for use of automobile and truck, interest on capital used in the enterprise, and miscellaneous expenses.

The cost of producing eggs will, of course, vary widely, depending chiefly on the prices of feeds and the cost of labor. The cost per dozen eggs will be much less when the annual egg production per hen is high than in a flock with poor egg production. Labor-saving equipment and efficiency in the use of labor are important in reducing the cost. Where egg production is the chief source of income or an important source, enough hens must be kept to utilize equipment and labor efficiently.

The most extensive studies of the costs of egg production in commercial flocks have been by the N.Y. (Cornell) Station.[11] For many years costs have been determined on a large number of commercial poultry farms in the state. During this time the average annual egg production per hen has increased steadily, because of improved nutrition, breeding and management.

For example, in 1926 the average was only 126 eggs per hen on the farms studied. By 1935, the average yield had increased to 150 eggs a year, by 1945 to 172 eggs, and in 1952 to 188 eggs.

In 1952, 113 lbs. of feed were consumed per hen a year, and 1.7 hours of labor were needed. Per dozen eggs, 7.2 lbs. of feed and 0.11 hour of labor were required.

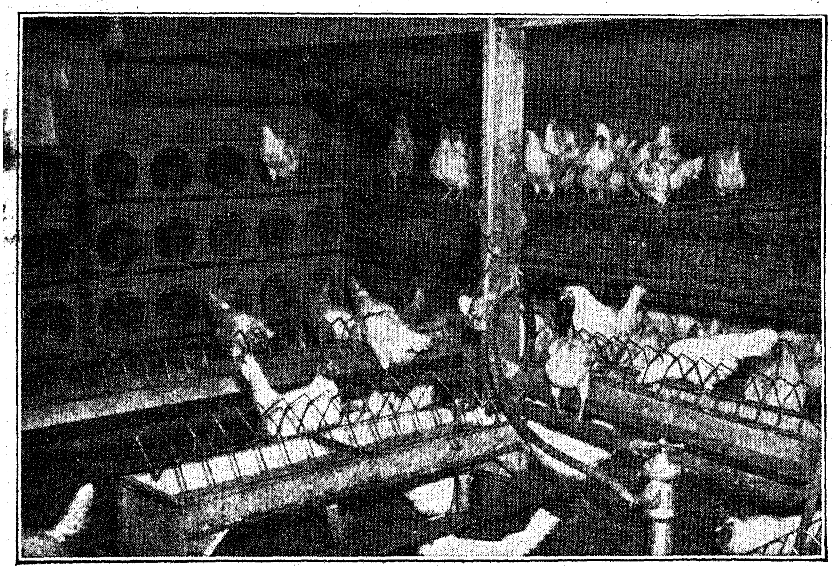
The cost of feed was 60.4 per cent of the total cost; labor, 17.0 per cent; flock depreciation, 11.3 per cent; and other costs, 11.3 per cent.

From these studies, a formula was developed for estimating the cost of

producing market eggs at any time in this area.[12] According to this formula, the average cost per dozen eggs is estimated as follows: Add together the cost of 7.2 lbs. of feed, 0.11 hour of labor, and 3.5 per cent of the farm value per bird (this item to cover flock replacements and depreciation). Increase this total by 13 per cent to cover the other costs.

the net returns per hen and per hour of labor in this study were decidedly greater from the Leghorn flocks than from the flocks of heavy breeds.

The cost of raising pullets for replacement was the same with the heavy breeds when straight-run chicks of both sexes were used, as it was in Leghorn flocks with sexed female chicks.[14] However, when sexed female heavy-breed



A Well-Arranged Laying House

The equipment is arranged so that only the minimum amount of labor is needed in feeding and caring for the flock. (From Ogle, New York State College of Agriculture, Cornell University.)

chicks were reared, the cost per pullet was 9 per cent higher. The difference was due to good returns from the male chicks, sold as broilers, from the straight-run heavy-breed chicks.

In studies for 1950–51, Leghorn flocks producing market eggs averaged 1,099 layers per flock, yielded 203 eggs per hen, and required 6.8 lbs. of feed per dozen eggs.[13] Flocks of heavy breeds averaged 820 layers per flock, yielded 192 eggs per hen, and consumed 7.6 lbs. of feed per dozen eggs.

In the Leghorn flocks, the hens disposed of for meat averaged 4.7 lbs. in live weight and brought an average of $1.07. In the heavy-breed flocks, the hens sold averaged 6.5 lbs. and brought $1.98.

Considering all costs and the returns for both eggs and for birds sold,

II. Raising Chickens

1571. Selection of breeding stock.—Just as is the case with other livestock, good returns cannot be expected from poultry unless one has a flock of birds that have high productive capacities and strong constitutions. The feeding of an ideal ration and the best of care will not compensate for a lack of inherited productive capacity.

It is outside the scope of this volume to discuss the principles and methods of livestock breeding and selection. Only certain summary statements can therefore be made concerning the selection of poultry for breeding. The fowls should be carefully selected for the following characteristics:

The strain should produce strong, vigorous chicks that make rapid growth and mature early. The pullets should begin to lay in the fall and continue a high rate of production steadily through the winter, without any "winter pause." The eggs should be of good size, shape, and color and of high hatchability. The strain should be resistant to disease, should not have a tendency toward cannibalism, and should be long lived.

It will pay every poultryman who saves his own eggs for hatching to follow some method of banding throughout the year, in order to identify the hens that have these desirable characteristics. He will then be able to separate the best hens in the flock and to save eggs for hatching only from them. A close observer can usually distinguish between hens that are layers and those that are not. However, the breeder who wishes to build up a high-producing flock should not rely on observation alone, but he should install trap nests and find out not only which hens are laying, but also how many eggs each lays.

Yearlings or older hens are much preferable to pullets for the production of eggs for hatching. They have proved their ability to live through the first year as layers, and have been retained for another year because they were good producers. Chicks from hens' eggs are generally larger than those from pullets' eggs. Also, in Ohio tests, the mortality during the first year of pullet layers hatched from yearling hens' eggs was considerably less than of pullets hatched from eggs produced by pullets.[15]

When chicks are purchased from a hatchery, one should be sure that they come from healthy, vigorous birds that have been bred for high production.

1572. Feeding and management of breeding hens.—To secure eggs of high hatchability which will produce strong vigorous chicks, the breeding hens must be fed a complete, well-balanced ration.[16] Any deficiency, no matter whether of protein, minerals, or vitamins, is apt to lower the hatchability seriously or to result in weak and unthrifty chicks. For the production of high-quality hatching eggs, the breeding flock must not only be fed properly during the hatching season, but also for some time previously.

The hatchability is generally better when the hens are fed a ration containing a fair proportion of protein supplements of animal origin, such as milk by-products, meat scrap, and fish meal, than when it contains only plant-protein supplements. It is stated in the preceding chapter that for breeding hens the mash to be fed with grain should contain 7 to 10 per cent of animal-protein supplements. (1501) For layers, not producing hatching eggs, 5 to 7 per cent of animal-protein supplements is satisfactory in a mash to be fed with grain.

In the production of eggs for hatching, care must be taken to meet the mineral needs. Experiments have shown that a lack of calcium decreases hatchability. Also, as shown in the preceding chapter, 15 milligrams of manganese per pound of feed is needed in a ration for breeding hens to secure good hatchability. (1511)

A deficiency of vitamins is probably the factor that most frequently lowers hatchability. An ample supply of vitamin A and of vitamin D is essential. However, no greater allowances of these vitamins are considered necessary for breeding hens than for hens producing market eggs. (1498) On the other hand, larger amounts of riboflavin, pantothenic acid, and folic acid are advised for breeding hens.

Sunlight which has not passed through window glass provides vitamin D. In addition, certain experiments indicate that even when there is plenty of vitamin D in the ration, the hatchability is improved when hens are exposed to direct sunlight.

Supplying breeding hens with fresh green feed tends to increase hatchability.

When this is not available, it is important to include in the ration a sufficient amount of alfalfa hay, alfalfa leaf meal, or a satisfactory substitute.

To secure high hatchability, the hens must be kept in good physical condition. Before they can produce satisfactory eggs for hatching, yearling hens need a rest period after heavy production in their pullet year. During this rest period, they molt, grow a new set of feathers, regain any lost weight, and build up stores of nutrients in their bodies.

About 3 months should be allowed for this rest period and for getting the hens back into full production. The hatchability is generally not satisfactory until hens have reached a good level of laying, and it is usually higher for high producers than for poor layers.

1573. Saving eggs for hatching.—To insure high fertility of eggs for hatching, a sufficient number of well-bred, vigorous roosters should be placed with the hens. With vigorous males, one is generally provided for each 15 to 20 hens of the egg breeds, and for each 10 to 15 hens of the general-purpose breeds.

Although some fertile eggs may be produced about 24 hours after males have been placed with the hens, a satisfactory level of fertility is not likely to be reached until after about a week, and for maximum fertility, 10 days may be needed.

Medium-size eggs are best for hatching.[17] The hatchability is usually lower from very small or from extremely large eggs.

Care must be taken to keep eggs clean that are to be hatched. Eggs may be held, without any apparent loss of hatchability, for a week or even somewhat longer at a temperature of 50 to 55° F. before they are incubated. When eggs are thus held, it is a good plan to stand them on the small end in ordinary egg case fillers. If eggs for hatching are held for more than a week or 10 days, they should be turned once a day. A simple way to turn eggs sufficiently in an ordinary egg case is to tilt the case daily by placing a block under one end of the case.

1574. Best time for hatching chicks.—In order to secure the best returns from egg production, it is important that the chicks be hatched early enough in the spring so that the pullets will lay well in fall and early winter, when egg prices are ordinarily highest. Too often, at this time the pullets in farm flocks have not begun to lay, and the old hens are not laying, but are molting.

Pullets of the lighter breeds, such as Leghorns, should come into laying when 5 to 6 months old, and those of the heavier breeds, when 5½ to 6½ months old.

Another advantage of early-hatched chicks is that those which are hatched late generally do not do so well as early chicks, because of the hot weather in summer. A third advantage of early-hatched chicks is that the males may be sold as broilers early in the season when prices are usually slightly higher than later.

In commercial poultry plants, some pullets are often reared at other seasons of the year. This makes it possible to replace birds that die or are culled out; to secure more uniform egg production throughout the year; to make more efficient use of labor and brooding equipment; and to secure a greater number of offspring from the fowls of outstanding merit.

In a New York survey of the results on large-scale poultry farms, it was found that fall-hatched pullets, put into the laying house in April, produced a greater net return than spring-hatched pullets.[18] However, where the winter climate is cold, unless excellent facilities are provided for raising fall-hatched pullets, they are apt to be much less satisfactory than those hatched in the spring.

1575. Hatching the chicks.—In all intensive poultry districts of the United States, incubators have replaced hens for hatching chicks. However, in some sections of the country a considerable percentage of the chicks are still hatched by hens.

Modern incubators are easy to operate, if the directions furnished with the machine are carefully followed. After each

hatch, the incubator should be thoroughly cleaned and disinfected to prevent the spread of disease. Before putting in the eggs, the temperature should be checked for at least a day to see that the regulator is adjusted.

The eggs are tested during incubation, and all infertile eggs and those with dead embryos are removed. The hatch should be completed by the end of the twenty-first day of incubation. None of the chicks should be taken out of the incubator until they have dried off and are "fluffed out." When they are removed, they should be placed where they will not be chilled.

At elevations of 5,000 feet and above, the hatchability of eggs is commonly much lower than at low elevations. In recent experiments it has been found that this is due to the reduced oxygen content of the air at the high elevations.[19] By increasing the oxygen in the incubator air approximately to the percentage at sea level and also controlling the carbon dioxide content, normal hatchability is secured.

1576. Hatching eggs with hens.—When eggs are hatched with hens, clean nests should be prepared in a dark, cool, well-ventilated, and quiet place. The nest should be about 16 inches square. It should be of such depth that the chicks cannot fall out at hatching time, while it is shallow enough so that the hen will not have to jump down into the nest. It is best to place the nest box on the floor so the hen can get into it readily.

Oat straw is the best nesting material, and wheat straw, hay, or leaves are preferable to shavings. The straw or hay should be cut into 6-inch lengths if it is too long. It is well to place a hollowed-out sod or some soil in the bottom of the box, to provide moisture. The straw should be put over this and rounded into a nest shape, with the nest a trifle deeper in the center than it is at the sides, to keep the eggs from rolling out.

The hens should be examined carefully for lice. If any are found, the hens should be dusted thoroughly with sodium fluoride powder before setting them, and again after 10 days. This will rid the hens of lice and prevent the chicks becoming infested.

After placing 2 or 3 nest eggs in each nest, the hens are moved to the nest just at dark. The next day they should be taken off and given feed and water. If they do not return to the nests in 20 to 30 minutes, they must be driven back or caught and confined to the nest. As soon as the hens settle down, they should be given the eggs. Until hatching starts, the hens should be taken off or allowed to come off daily.

The hens should be fed whole or cracked grains, such as corn or wheat, and occasionally some green feed. The feed should be kept near, so that the hens will not have to leave their nests for a long time to get feed. Grit and fresh water should be placed where the hens can get them when they come off the nests daily.

1577. Artificial brooding.—When a large number of chicks are raised, brooders are generally used instead of rearing the chicks with hens.[20] By this method the chicks can be raised at any desired time, and much labor is saved. Brooders are of three types—portable brooders, continuous brooder houses, and battery brooders. Except in very large poultry plants, the portable brooders are most common. These can be moved to fresh, uncontaminated ground each year, so that the chicks can be raised under the most favorable conditions. Brooders are usually heated by coal, oil, or electricity.

Before the chicks are put into the brooder, the house, the hover, and all utensils should be carefully cleaned and disinfected, if the brooder has been used before. One should be sure that the house is free of mites.

Chicks are generally left in the incubator 24 to 36 hours after hatching, before they are removed to the brooder. This should have been in operation for 2 to 4 days before the chicks are placed in it, in order to see that the temperature is regulated properly.

The first day, the brooder is kept at a temperature of 94° or 95° F. The

temperature may then be lowered uniformly about 0.8° F. a day until it reaches 70° F.

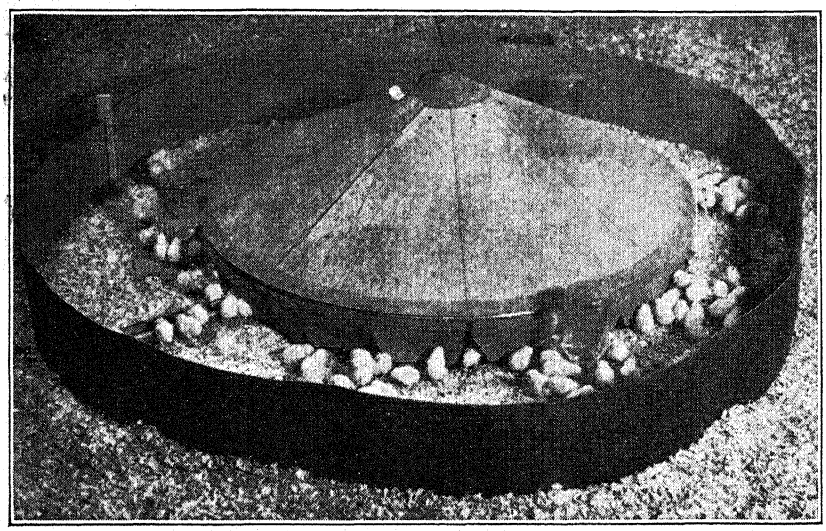
The heat is usually discontinued when the chicks are well feathered. Early in the spring it may be needed for 8 to 12 weeks in the northern states, and for only 4 to 6 weeks later in the season.

The chicks should have chick starter and water or milk available as soon as they are placed in the brooder house. To keep them from straying away from the hover to the corners of the house, a guard of one-half inch wire mesh should be placed around the hover and 2 or 3 feet from its edge. This may be covered with burlap sacking at first to protect the chicks against cold floor drafts. The space inside is gradually enlarged, and the guard is usually removed when the chicks are about a week old. Pieces of wire mesh or else boards should be placed across the corners of the house to prevent the chicks from crowding into the corners and some being smothered by the piling up.

The floor of the brooder under and around the hover should be covered with fine litter, such as cut straw, shavings, cut alfalfa or clover hay, peat moss, or finely ground corn cobs. Sometimes sand is used. Combustible litter must be kept away from the stoves. An advantage of using cut alfalfa or clover hay for the first 3 or 4 days is that it is partly digestible and is not apt to cause impaction if the chicks eat it.

For disease control, it is important to keep the litter dry. A layer of 2 to 3 inches of litter is enough at first, but by the time the chicks are 8 to 10 weeks old, the litter should be 4 or 5 inches deep. The litter should be stirred up daily to keep it dry. Any wet litter around the drinking fountain should be replaced with fresh material or with dry litter from other parts of the floor.

In suitable weather at 5 to 6 days of age, when the chicks have learned where to go to get warm, they may be allowed to run out into a small outdoor yard. A sloping runway should be made by piling dirt in front of the chick door, so the chicks can readily get in and out of the brooder house. After the chicks learn how to find their way back to the



A Simple Electric Brooder

The chicks are in a clean house with clean litter. Note the chick guard around the hover, the waterer in the right foreground, and the feeders for the chick starter. (From Ogle, New York State College of Agriculture, Cornell University.)

house, the enclosure can be removed and the chicks allowed to range at will.

Low roosts should be placed in the brooder house when the chicks are 3 to 4 weeks old, so that they will learn to roost at an early age. This will prevent them from crowding together on the floor at night, and becoming overheated or even smothered. In hot weather good ventilation of the house is essential.

It is best to separate the males which are to be sold as broilers by 8 weeks of age, if they can be identified. They can then be fed a broiler mash until they are sold, while the pullets are fed a growing mash and otherwise managed for the production of layers.

1578. Brooding chicks with hens.—In rearing chicks with hens, the essentials are few. A quiet, motherly hen should be placed in a portable coop which will allow the chicks free range but in which the hen can be confined if desired. The coop should protect the hen and the chicks from the weather and from enemies, and should be located on a grassy, shady range. Early in the season, it is usually best to have board bottoms in the coop, but later in the season and in dry weather this is not necessary. When board bottoms are used, they should be covered with cut litter or sand, which should be changed at least once a week. When no bottoms are used, the coop should be moved to a fresh spot at least every other day. This will prevent killing the grass and will fertilize a larger area.

As soon as the chicks are 10 days old, the mother hen may be turned loose toward night and allowed to run with the brood. She can be given her liberty during the day when the chicks become accustomed to following her. On most farms, the hens with their broods can be moved to some field where they can find a large part of their living.

As soon as the chicks are old enough to look out for themselves, which will be in 4 to 6 weeks in warm weather, the hen may be removed. The chicks will do better by themselves, and the hen will start laying sooner if separated from the chicks.

When the chicks are hatched in incubators or are purchased from hatcheries, broody hens are sometimes used to raise the chicks. They are each given a couple of chicks to test them out just at dark, and early the next morning the best mothers are selected and each given from 12 to 20 chicks.

1579. Nutrient requirements of chicks.—Because of the discoveries made concerning the nutrient requirements of poultry, it is now possible to raise thrifty chicks at any time of the year, and even in confinement and without any fresh green feed. The requirements of chicks and also of older fowls for the various nutrients have been considered in detail in the preceding chapter.

It will be noted that the committee of the National Research Council recommends that chick starters for feeding chicks during the first 8 weeks should contain 20 per cent protein. (**1498**) For chicks from 8 to 18 weeks of age, rations containing 16 per cent protein are advised.

It has been pointed out previously that chickens fed a high-energy ration need a slightly higher percentage of protein than do those fed rations containing more fiber. (**1499**) Consequently, the rate of gain may be a little more rapid on a high-energy ration, especially for chicks of the heavier breeds, if the ration has at least 21 per cent of protein for the first 6 to 8 weeks, and then at least 17 per cent.

Mashes for chicks to 8 weeks of age should preferably have not less than 5 to 7 per cent of protein supplements of animal origin. (**1501**) Mashes to be fed with scratch grain to growing chickens after 8 weeks should have at least 5 to 7 per cent of animal-protein supplements.

Chicks and growing chickens need a decidedly smaller percentage of calcium in their rations than do laying hens. As stated previously, 1.0 per cent of calcium is sufficient. (**1508**)

Rations for chicks and growing chickens should have at least 0.6 per cent phosphorus, and at least 0.45 per cent should be inorganic phosphorus. (**1509**)

If liberal amounts of animal-protein supplements are included in rations for chicks, there may be an ample supply of phosphorus. On the other hand, it will commonly be necessary to include a calcium supplement in the ration. It is important to include one-quarter pound of manganese sulfate in each ton of chick mash, to insure an adequate amount of manganese. (1511)

It will be noted in the preceding chapter that chicks require less vitamin A and vitamin D per pound of feed than do laying hens. (1517, 1519) On the other hand, chicks up to 8 weeks of age need a larger allowance of riboflavin per pound of feed than hens require. (1520)

The importance of vitamin B_{12}, of the unidentified vitamins or factors, and of other vitamins for chicks has been discussed in detail in the preceding chapter. (1523–1529)

Proper growth of chicks cannot be expected unless they are fed a ration that amply meets their requirements. Often farmers who feed good chick starters during the first few weeks, substitute only farm grains for the more expensive chick mash when the chicks are 2 to 4 weeks old.

A North Dakota test shows the poor results produced by this practice.[21] Chicks fed only grain after they were 3 weeks old averaged only 0.82 lb. in weight at 11 weeks of age, while others fed a well-balanced mash averaged 1.95 lbs. Both groups were then fed a balanced ration, but at 22 weeks of age the pullets which had been fed only grain for a time were 0.7 lb. lighter than those fed properly at all times. Also, three-fourths of the pullets fed inadequately for a time had crooked breast bones, and their bones were weak.

1580. Feeding the chicks.—Baby chicks should be given feed and water as soon as they are placed in the brooder. Some years ago it was a common practice to withhold feed from chicks for 60 to 72 hours after hatching. During this time they secure nourishment from the remainder of the yolk, which is drawn into the body just before hatching.

While strong chicks can usually go without feed for this length of time without injury, it is difficult for some to stand the strain. Investigations have shown that it is decidedly preferable to supply feed as soon as the chicks are put in the brooder. Otherwise, they are apt to eat litter and droppings. The ability of chicks to live for a few days upon the remainder of yolk within their bodies makes it possible to ship baby chicks from hatcheries for a considerable distance.

The feed for baby chicks should be easily accessible, and there should be plenty of feeding space, so that they will learn to eat readily. About 1 inch of feeder space should be allowed per chick to 2 weeks of age, and 2 inches after that.

For the first 2 or 3 days, some of the chick mash, or chick starter, should be fed twice a day in small trough feeders about 1 inch deep and 2 or 3 inches wide. Sometimes chicks are given their first feeds on newspaper or cardboard. However, there is then danger of the droppings becoming mixed with the feed, which may spread disease. When the chicks have learned to eat, larger trough feeders should be used, with guards to prevent the chicks getting into the feed. Such feeders lessen feed wastage and keep the droppings out.

As soon as the chicks have learned to eat from the feeders, both the feeders and the fountains should be placed on platforms which are 6 inches high and covered with wire or slats. This prevents the litter from being scratched into the feeders or fountains, and the chicks do not come in contact with the wet spots where water may be spilled from the fountains.

After the chicks are 8 or 10 weeks old, larger feeders are used. If the chicks have outside range, most of the feeding may be done in protected outdoor feeders. Even then, it is well to have one feeder in each brooder house for rainy days.

For the first 4 to 8 weeks, chicks

are generally fed only chick starter, or chick mash. After this, a common method is to feed chick-size grain in addition to mash. However, many poultrymen continue the all-mash method during the entire growing period. All-mash rations are generally used in broiler production. Sometimes the mash for chicks is fed in the form of pellets or crumbles. (**1544**)

If the rations are equally well balanced, the results are about equal from all-mash rations for raising chicks, and from feeding grain in addition to mash, after the chicks are 4 to 8 weeks old.[22] As stated previously, chick starter mashes for the first 8 weeks should have not less than 20 per cent protein. After about 8 weeks of age, grower mashes for all-mash feeding should have at least 16 per cent protein.

Mashes for feeding with grain must be higher in protein and in mineral and vitamin supplements than a mash used in the all-mash method.

When grain is fed in addition to mash, chick-size grit should be supplied. (**1514**) In all-mash feeding, the entire amount of calcium supplement needed is included in the mash, and no grit is necessary.

Occasionally, there is trouble from diarrhea in chicks during the first week, which causes the condition known as "pasting up." This seems to be most apt to occur on a mash high in soybean oil meal. Experiments have shown that the trouble can usually be prevented by feeding only chick-size scratch grain, or else grain in addition to mash, during the first 2 or 3 days, instead of mash alone.[23]

Liquid skimmilk or buttermilk is excellent for chicks, and may be given as the only drink for the first 3 to 4 weeks. At 4 weeks of age pullets should get water in addition, so as to reduce the protein content of the ration and prevent too rapid development. Cockerels intended for broilers may get only milk to drink until they are sold.

Fresh, uncontaminated range should be provided for the chicks as soon as the weather is suitable. While chickens can be raised in confinement when a complete ration is fed, the pullets will commonly be much more thrifty and also more productive if they have been raised on good range. Raising chickens in confinement is preferable, however, to allowing them to become diseased and infected with parasites by ranging over badly contaminated ground. If fresh range cannot be provided for chicks, it is the best plan to let them have access during the day to a sun porch floored with wire netting.

Several example rations for chicks are given in Appendix Table VII which are adapted to various sections of the country. Statements are also there made concerning the ways in which these rations may be changed to adapt them to local conditions.

1581. Raising pullets and cockerels.—Wherever possible, the pullets should be reared in a movable colony house on clean, uncontaminated pasture. They should be kept entirely separate from the older chickens, so as to avoid the spread of disease and parasites.

The pullets must be fed liberally, so that they will make good growth and be ready to start laying in the fall. The most common method of feeding is to supply a suitable mash in hoppers and also a mixture of grain. Sometimes the all-mash method of feeding is used. Water and grit should be accessible at all times, and oyster shell or some other calcium supplement should be provided separately, if a sufficient amount is not included in the mash.

In a recent Wisconsin experiment pullets were raised to 20 weeks of age on an all-mash, corn and vegetable-protein ration with a vitamin B_{12} supplement.[24] Other groups received rations containing also an antibiotic supplement and, in addition, fish solubles or fish meal to supply unidentified growth factors. After 20 weeks all groups were fed a complete, well-fortified laying ration.

The pullets raised on the complete rations were heavier at 20 weeks, and slightly heavier at a year of age. There were no appreciable differences in the amount of feed required per pound of

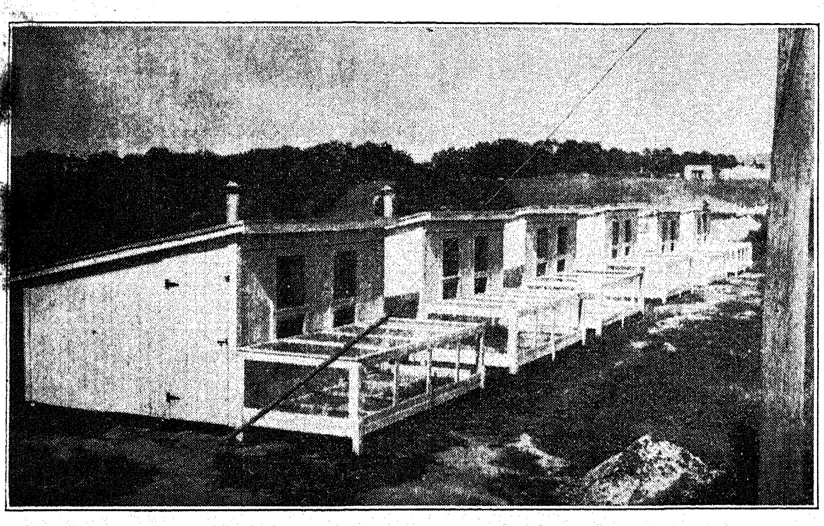
gain by the different groups. The pullets fed the first ration started laying 10 to 12 days later than those fed the complete ration, but they laid about as many eggs during the laying year.

Sometimes the raising of pullets on a moderately restricted amount of feed is advocated. However, this delays the beginning of laying, and it does not seem to make any appreciable saving in the total amount of feed consumed up to the beginning of egg production.[25]

hens, to avoid the spread of disease and parasites.

The greatest danger of feather picking and cannibalism developing comes the first few weeks after the pullets are put in the laying house. Common causes are overcrowding or an inadequate ration.

The cockerels to be retained for breeding are usually selected at the broiler stage. They should be chosen on the basis of vigor, rapid growth,



BROODER HOUSES WITH SUN PORCHES

Rearing chickens in confinement in this manner is advisable only when fresh, uncontaminated pasture cannot be provided. (From Hurd, New York State College of Agriculture, Cornell University.)

Experiments show that when pullets have unlimited range on excellent pasture, such as Ladino clover or Ladino and grass, they may make satisfactory growth and develop properly when fed only grain with mineral supplements after they are 7 to 10 weeks of age.[26] Sometimes, however, pullets thus fed will not grow so rapidly or start laying so soon.

The pullets should be moved to the laying house 1 to 3 weeks before they are ready to lay. They should always be handled carefully, so that they do not become frightened. If possible, the pullets should be housed separately from

early feathering, moderate comb development, and good pigmentation of shanks. It is desirable to retain three times as many cockerels as will be needed for breeding, so that later they can be thoroughly culled. The cockerels should have a separate range, and should be fed about the same as the pullets.

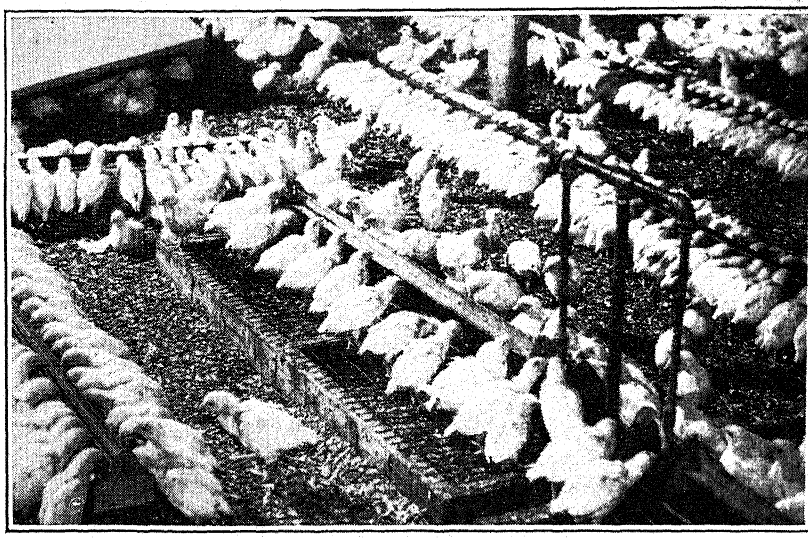
In the case of breeds which have large combs, many poultrymen dub the combs and wattles of cockerels that are to be retained for breeding. This means that most of the comb and wattles are cut off, in order to avoid injury later from freezing or fighting. Males which have been dubbed are usually in better

condition at the beginning of the breeding season and are more fertile than undubbed males. The dubbing is generally done when the cockerels are 8 to 12 weeks old.

1582. Production of broilers.—The production of broilers has become a very important year-around industry in some areas of the United States. In 1954 about 800,000,000 chicks were used for broiler production in only the 14 chief broiler-producing areas of our country.[27]

In addition to the specialized broiler plants, on egg-producing poultry farms the surplus cockerels are generally marketed as broilers.

For specialized broiler production, cross-bred chicks of the heavy breeds are generally used, because of their more rapid growth. A popular cross is produced by mating White Plymouth Rock males to Cornish or other females. Sometimes chicks of the heavy breeds are used instead of cross-breds.



ARRANGEMENT FOR WATERING BROILERS IN LARGE PLANT

In large-scale broiler production, feeding and watering facilities are provided to save as much labor as possible.

The term "broiler" is now commonly used for chickens of either sex which are finished for marketing when 8.5 to 12 weeks old and weighing 3 to 4 lbs. alive. Sometimes the heavier broilers are called "fryers."

Broiler production is chiefly a highly specialized, large-scale enterprise. Such producers have plants in which 10,000 to 20,000 or more broilers are raised at a time, and 4 or even more batches are produced a year. To provide a steady supply of finished broilers throughout the year, chicks are started nearly every week in the important producing areas.

1583. Feeding broilers.—For efficiency in broiler production, it is essential that a ration be used which fully meets all the nutritive requirements for very rapid growth. On such a ration not only is less feed required per pound of gain, but also rapid growth produces tender meat.

The nutritive requirements for chicks and growing chickens have been discussed in detail in the preceding chapter. Further information on the special nutrient needs of chicks and methods of feeding has been given earlier in this chapter. (**1579–1580**)

Essentials in rations for economi-

cal broiler production are: (1) High-energy rations, which are necessary for a maximum rate of growth and for efficiency of gains; (2) protein of excellent quality, which furnishes plentiful amounts of the essential amino acids; (3) a proper supply of minerals; (4) ample amounts of the various needed vitamins, including vitamin B_{12} and also the unidentified vitamins or factors; (5) an effective antibiotic feed supplement. All these requirements for rapid and efficient growth have been fully discussed previously.

The remarkable increase in efficiency of broiler production made possible by the recent discoveries in poultry nutrition has been pointed out in the previous chapter. (1495) Only a few years ago more than 4 lbs. of feed were required on good rations per pound of broiler marketed. Now broilers have been produced on modern, complete rations with only 2.2 lbs. of feed per pound of gain.

All-mash rations are generally used for broilers, and this method of feeding is usually continued until the broilers are marketed. When the chicks are about 6 weeks old, cracked grain is sometimes fed in hoppers, in addition to the mash. This method produces good results when a mash is used that contains about 20 per cent or more protein.[28]

Broilers with yellow color in the skin and shanks are preferred on the market. Therefore, a sufficient amount of feeds that produce yellow color in body tissues should be included in the ration, such as yellow corn, corn gluten meal, and alfalfa meal or alfalfa leaf meal. (1518)

1584. Fattening or finishing chickens.—When the surplus cockerels are marketed as broilers, they can be sold direct from the range if they are in good flesh, or they may be put in pens or crates and fed a special fattening ration for 10 to 14 days or longer. Such a ration is fed when fattening caponettes, or hormonized broilers. (1540) Also, fattening rations are used for the production of capons, and hens and roosters are often fattened thus before they are marketed, in order to improve the quality of the carcasses.

In such fattening the mash may be mixed to a batter with skimmilk, buttermilk, or water, so the birds will eat more feed than if fed a dry mash. The birds are started on the fattening ration carefully, and then after 2 to 4 days they are given twice a day or oftener as much of the batter as they will clean up. Supplying water or milk to drink is unnecessary, except in hot weather, because of the large amount of liquid in the batter.

The ration need not be so nutritionally complete during this brief fattening period as in the growth period. It generally consists mostly of finely-ground grains. Fat is sometimes added to the mash in order to increase the productive energy, and thus hasten the fattening. (1506) No fish oil or fish meal should be included in a fattening ration, to avoid danger of tainting the meat. It is not necessary to supply grit or oyster shell during the fattening period.

1585. Growth of chickens and feed required.—The publication on "*Nutrient requirements for poultry*" by the special committee of the National Research Council, to which references have been made previously, gives the estimates on the next page of the ages at which chickens should reach certain live weights.[29] Also, the approximate amounts of feed are stated, which are required per bird to reach these live weights.

The table shows that White Leghorn females should reach an average weight of 2.5 lbs. at 14.6 weeks of age, and males at 11.1 weeks. The females of the heavy breeds should reach a weight of 3.0 lbs. at 11.3 weeks, and the males at 10.0 weeks.

Up to a weight of 2.5 lbs., White Leghorn females will eat approximately 10.6 lbs of feed, and males 8.1 lbs. To a weight of 3.0 lbs., females of the heavy breeds will consume about 10.0 lbs. of feed, and males about 8.0 lbs.

III. Turkeys

1586. Production of turkeys.—The great increase in the production of tur-

keys for meat which has occurred in this country during recent years has been made possible only through the discoveries concerning poultry nutrition and disease prevention. Instead of being only a holiday treat, turkey meat has now become a staple and economical food.

It will be noted in Chapter XII that according to recent estimates by Jennings of the United States Department of Agriculture, turkeys rank next to pigs in the efficiency with which they convert their feed into protein and energy in food for humans. (352)

It was formerly considered impossible to raise turkeys successfully unless they had free range. However, when free range was provided, there were often very serious losses from blackhead or other diseases or from infection with internal parasites.

With the development of modern, complete rations for poultry, it was found that thrifty turkeys could be raised entirely in confinement or in semi-confinement. These results have made it possible to raise turkeys commercially on an intensive basis in sections where former attempts at large-scale turkey production often failed.

One method of raising young turkeys is to confine them in the brooder house and an adjoining sun porch floored with wire netting until they are ready for market. The house is cleaned regularly to prevent the spread of disease or parasites. This system is preferred when uncontaminated pasture is not available.

In the semi-confinement system the day-old young turkeys, called poults, are started in a brooder house, with or without an attached sun porch. In order to avoid disease and parasites, they are not permitted to touch the ground until they are old enough to go on fresh, uncontaminated pasture, usually at 8 to 12 weeks of age. This system is commonly preferred when clean pastures are available, and when enough turkeys are grown to warrant the extra work of feeding and caring for them on the pasture.

Age to reach certain live weights, and feed required

Average live weight	Age at which the live weight is reached				Quantity of feed required per bird			
	White Leghorns		Heavy breeds		White Leghorns		Heavy breeds	
	Females	Males	Females	Males	Females	Males	Females	Males
Lbs.	Weeks	Weeks	Weeks	Weeks	Lbs.	Lbs.	Lbs.	Lbs.
0.5	3.8	3.4	3.2	2.9	1.0	1.0	0.8	[illegible]
1.0	6.0	5.4	5.4	5.0	2.5	2.3	2.2	[illegible]
1.5	8.6	7.5	7.2	6.7	4.3	3.7	3.8	3.3
2.0	11.2	9.3	8.7	8.0	6.3	5.9	5.3	4.6
2.5	14.6	11.1	10.0	9.0	10.6	8.1	7.2	6.2
3.0	19.2	13.2	11.3	10.0	15.6	11.0	10.0	8.0
3.5	26.6	....	13.6	10.9	24.3	....	12.3	10.0
4.0	30.8	....	....	....	....	....	17.3	12.9
4.5	....	....	....	....	....	....	22.0	....
5.0	....	....	....	....	....	....	29.0	....

1587. Nutrient requirements of turkeys.—Largely because they grow more rapidly than chickens, poults require a greater percentage of protein in their ration than do chicks.[30] Also, their requirements, per pound of feed, for calcium, phosphorus, vitamin A, vitamin D, and riboflavin are higher than those of chicks.

The nutrient requirements of turkeys, as stated in the revised 1954 report of the special committee of the National Research Council, are shown in the following table. It should be noted that these revised standards are estimates of the minimum requirements, and they do not include any margins of safety, such as there are generally in other feeding standards for cattle, sheep, horses, and swine.

In making up practical rations, the

amounts of nutrients provided should be sufficiently greater than these minimum requirements to cover variations in the composition of feeds and differences in the requirements of individual birds. (1498)

On comparing the requirements stated in this table with the requirements of chickens which are given in the preceding chapter, it will be noted that the requirements of poults for protein, vitamin A, vitamin D, riboflavin, calcium, and phosphorus are decidedly higher than those of chicks. (1498) Breeding turkeys require about the same proportion of protein as do breeding hens, but hen turkeys need more vitamin A and vitamin D.

Nutrient requirements of turkeys [1]

	Starting poults 0–8 weeks	Growing turkeys 8–16 weeks	Breeding turkeys
Total protein, per cent [2]	28	20	15
Vitamins			
Vitamin A activity (U.S.P. Units.) [3]	2400	2400	2400
Vitamin D (International Chick Units)	400	400	400
Riboflavin, mg.	1.7	?	1.5
Pantothenic acid, mg.	5.0	?	?
Choline, mg.	750	?	?
Folacin, mg.	0.4	?	?
Minerals			
Calcium, per cent	2.0	2.0	2.25 [4]
Phosphorus, per cent [5]	1.0	1.0	0.75
Manganese, mg.	25	?	15
Salt, per cent [6]	0.5	0.5	0.5

1 These figures are estimates of requirements and include no margins of safety.
2 The protein content of rations for growing turkeys from 16 weeks to market weight may be reduced to 16 per cent.
3 May be vitamin A or carotene.
4 This amount of calcium need not be incorporated in the mixed feed, inasmuch as calcium supplements fed free choice are considered as part of the ration.
5 At least 0.50 per cent of the total feed of starting poults should be inorganic phosphorus. All of the phosphorus of non-plant feed ingredients is considered to be inorganic. Approximately 30 per cent of the phosphorus of plant products is non-phytin phosphorus and may be considered as part of the inorganic phosphorus required. Presumably a portion of the requirement of growing and breeding turkeys must also be furnished in inorganic form.
6 This figure represents salt or sodium chloride added as such or in marine or fermentation products of high sodium chloride content.

Experiments have shown that the vitamin D in cod-liver oil or sardine oil has a lower relative efficiency for turkeys than it does for chickens, in comparison with the efficiency of vitamin D in the form of activated animal sterol. (202)

1588. Protein; amino acids.—The previous table shows that poults require 28 per cent of protein in the ration up to 8 weeks of age, and 20 per cent from 8 to 16 weeks of age. The recommended level of protein in rations for poults is therefore considerably higher than for chicks. (1498) Breeding turkeys need only 15 per cent of protein in the ration, which is the same percentage required by hens.

The special committee of the National Research Council states the requirements of certain of the essential amino acids in a 28-per cent-protein starting ration for poults to be as follows: Arginine, 1.6 per cent; glycine, 1.0 per cent; isoleucine, 0.84 per cent; lysine, 1.5 per cent; methionine, 0.87 per cent, or else methionine, 0.52 per cent, plus cystine, 0.35 per cent; and tryptophan, 0.26 per cent.[29]

The manner in which an amino acid deficiency can be corrected in a practical poultry ration has been discussed in the preceding chapter. (1503)

In recent experiments with poults fed a corn-soybean oil meal type starting ration, satisfactory growth was secured with only 20 per cent protein, when pure methionine and lysine, two of the

essential amino acids, were added.[31] This indicates that the need for the high level of 28 per cent protein in the usual practical rations is to supply sufficient of these amino acids. Synthetic methionine is now available commercially at a price that makes its use practicable in correcting a methionine deficiency in poultry rations. However, the cost of synthetic lysine is yet much too high to make its use practicable.

The results of the experiments in which methionine has been added to practical rations for poults have been similar to the trials with chicks or broilers.[32] (**1504**) In the majority of the tests the feed efficiency has been improved slightly, and in some the rate of gain has been increased a little.

It has been found that a deficiency of lysine in the ration causes a bleaching of the feathers of Bronze poults, resulting in some white feathers.[33] This can be prevented by including in the ration a sufficient percentage of feeds high in lysine, such as meat scrap, tankage, fish meal, or dried skimmilk.

1589. Fiber; high-energy rations.— Turkey poults can make good growth on rations containing a higher percentage of fiber than is satisfactory for chicks. However, with a high level of fiber considerably more feed is required per pound of gain. High-energy rations are therefore generally more economical, unless a ration lower in productive energy is much cheaper.[34]

In a Pennsylvania trial with turkey pullets a ration supplying 882 Calories of productive energy per pound was compared with rations having lower energy contents.[35] The feed efficiency and the hatchability of the eggs were best on the high-energy ration. However, there was not much difference in the egg production, the fertility of the eggs, or in the maintenance of body weight on the various levels of energy.

A Utah experiment shows that after poults are 8 weeks old, they will make satisfactory growth on a ration containing as much as 35 per cent of good-quality alfalfa meal.[36] The rate of gain to 29 weeks of age was as high as with less alfalfa meal, and only a little more feed was required per pound of gain.

YOUNG TURKEYS ON GOOD RANGE

Note the waterer in the foreground, which is on a platform covered with wire mesh. (From Smith, New York State College of Agriculture, Cornell University.)

1590. Minerals.—The requirements of turkeys for calcium, phosphorus, manganese, and salt are shown in the previous table of "*Nutrient requirements of turkeys.*" (1587) It will be noted that in rations for poults to 8 weeks of age and also for growing turkeys 2.0 per cent of calcium is required. This is double the percentage needed by chickens.

The requirement for phosphorus is also much higher than for chickens, being 1.0 per cent of the ration for young poults and also for growing turkeys.

Turkeys cannot tolerate as high a level of salt as can chickens. For example, in a Texas experiment including 2 per cent of salt in a ration for poults caused heavy mortality.[37] More than the recommended percentage of salt, 0.5 per cent, should not be added to the ration.

1591. Vitamins.—Turkeys require the same vitamins as do chickens, and the detailed discussions in the preceding chapter concerning the various vitamins for chickens apply in the main to turkeys as well. However, as will be noted in the table of nutrient requirements of turkeys, their requirement for the different vitamins is greater than in the case of chickens. (1498, 1587)

For example, poults up to 8 weeks old and also growing turkeys from 8 to 16 weeks of age need 2,400 U.S.P. Units of vitamin A activity per pound of ration. This is twice as much as required by young chickens. The vitamin A requirement of breeding turkeys is also higher than for hens.

The vitamin D requirement of young turkeys is especially high, being 400 International Chick Units of vitamin D per pound of ration, while young chickens need only 90 Units. Breeding turkeys also require 400 Units per pound of ration, which is nearly twice as much as hens need.

A deficiency of vitamin D or lack of calcium or phosphorus causes rickets in growing turkeys, and a deficiency of the vitamin in hen turkeys results in thin-shelled eggs and poor hatchability.

Experiments have shown that the vitamin D in cod-liver oil has a lower relative efficiency for turkeys than it does for chickens, in comparison with the efficiency of vitamin D in the form of activated animal sterol.[38]

Young turkeys need somewhat more riboflavin per pound of ration than do young chickens, as will be noted in the tables of nutrient requirements. Also, the riboflavin requirement of turkey poults seems to be increased when an arsonic supplement is added to the ration.[39]

Sometimes young turkeys are affected seriously by the "enlarged hock disorder" a few weeks before they are ready for market. This condition is different from perosis, or slipped tendon. The trouble seems to be due partly to a deficiency of an unidentified vitamin or factor, as the addition of 5 per cent of brewers' yeast has been effective in preventing it in some experiments.[40] In New York studies the adding of niacin, as well as brewers' dried yeast, was more effective than dried yeast alone.[41] On the other hand, in a Washington trial the addition of niacin to a ration did not prevent enlarged hocks.[42]

1592. Antibiotic feed supplements.—A detailed discussion of antibiotic feed supplements in poultry rations has been given in the preceding chapter. (1533–1535) The results from including an antibiotic supplement in rations for poults and growing turkeys have been similar to those secured with chicks and broilers.[43] An effective antibiotic supplement usually seems to increase the rate of gain of poults even more than that of chicks.

Just as in the experiments with chicks, streptomycin has in most trials with poults been less effective than penicillin, aureomycin, terramycin, or bacitracin. Also, as with chicks, in some trials a combination of antibiotic supplements has not been superior to a single effective antibiotic supplement.

An antibiotic supplement produces the most marked increase in growth of poults up to an age of about 8 weeks. However, the best results are secured when the use of the supplement is continued until the turkeys are marketed, just as in the case of broilers.

In the few experiments in which an

antibiotic supplement has been added to rations for hen turkeys, the results have differed, like the results of the trials with hens.[44] It therefore seems doubtful whether the use of an antibiotic supplement for hen turkeys will usually be economical.

Most of the antibiotic supplements are antibiotic-vitamin B_{12} feed supplements, which supply not only an antibiotic or antibiotics, but also vitamin B_{12}. The effect of such a supplement obviously may be due to the vitamin as well as to the antibiotic.

1593. Arsonic supplements.—The use of arsonic supplements in rations for poultry has been discussed in the preceding chapter and also in Chapter XXIII. (**1536, 967**) Very few experiments have thus far been reported in which these supplements have been tested in rations for poults.[45]

In these trials certain arsonic supplements, but not others, have tended to increase the feed efficiency slightly and also in some cases to improve the gains a little.

1594. Hormones.—The effects of certain synthetic sex hormones on poultry have been discussed in the preceding chapter. (**1540**) It is there shown that implanting a pellet or paste of diethylstilbestrol (commonly called "stilbestrol") under the skin of the head or upper neck a few weeks before slaughter usually improves the market finish of cockerels and increases the fatness and tenderness of the meat. Sometimes this treatment is combined with the addition of thiouracil to the ration during the finishing period.

Similar results have been secured in a few trials with young turkeys or with hen turkeys which are marketed at the end of the laying season.[46]

1595. Essentials in turkey production.[47]—For success in turkey production, it is even more necessary than with chickens that great care be taken to provide certain essentials.

Because the requirements of poults for protein, minerals, and vitamins are considerably greater than are those of chicks, the ration must fully meet these needs.

Strict sanitation is essential, or there may be very serious losses from disease. All equipment, including waterers and feeders, should be cleaned and disinfected regularly. This applies also to the incubator and to the brooder houses, before each use.

Feeders and waterers should be placed on screen or slat platforms, to prevent contamination from feces. On the range, feeders and waterers should be moved frequently. The poults should be fenced away from the droppings der the roosts.

Turkeys should be kept enti separate from all chickens. Any de birds should be burned, or else buri in fields that will not be used for tu for 2 years. Screen-floored sunpo attached to the brooder houses aid preventing infection from feces during the first few weeks.

For turkeys, only clean range should be used which has had no poultry on it for 2 years. The range should be well drained and have no stagnant water. Shade should be provided to prevent heat prostration. If possible, birds on range should be rotated to fresh areas during the season.

1596. Feeding growing turkeys.—Turkey poults may be fed the same sort of rations as chicks, except that the proportions of protein, mineral, and vitamin supplements should be larger, as shown previously. Generally, poults are fed a dry turkey-starter mash alone for the first few weeks. Chick-size grain may be supplied in addition, after the birds are 2 weeks old, and whole grain when they are about a month older.

The mash, or the ingredients, except oats, should not be ground very fine, and the mash should not be sticky when moistened. Otherwise, it may stick to the beaks of the poults.

During the first few weeks, oats should be included in the starter mash only if they are very finely ground, or pulverized. In Ohio and Texas experiments mashes with 10 to 20 per cent

of coarsely ground oats caused digestive disturbances and heavy mortality.[48]

After the poults are 8 weeks of age, the turkey-starter mash is usually replaced by a growing mash, which is lower in protein. A mixture of whole grain is commonly fed in addition, but sometimes 2 or more kinds of whole grain are fed instead. Many turkey producers feed pellets in addition to mash, or in place of it.

Grit is fed to poults once or twice a week, or else supplied in separate hoppers. Unless the mash contains ample calcium, oyster shell or limestone grit should be furnished. Plenty of water should always be accessible.

When turkeys are reared in confinement, it reduces the cost and improves their growth if they are fed fresh green feed daily. It is estimated that excellent pasture, such as has been previously recommended, may save 10 to 20 per cent of the concentrates required when turkeys are reared in confinement.[49] (1547)

If turkeys have been raised on a good ration, they need little or no special fattening during the last few weeks before they are marketed. Because of the danger of producing a fishy flavor in the flesh, turkeys should not be fed either fish meal or cod-liver oil or other fish oil, for at least 4, and preferably 8 weeks, before they are marketed.

Instead of marketing turkeys as roasters, at the usual age of about 28 weeks, a few producers market turkey broilers or fryers at the early age of 14 to 16 weeks.

1597. Feeding breeding turkeys.—Breeding turkeys may be fed much the same as hens, except that their rations should have somewhat more vitamin A, vitamin D, and phosphorus. They should not be given so much feed that they become too fat, or they may not lay well in the spring.

About a month before egg production is desired, electric lighting is used, to provide 12 to 14 hours daylight. At this time, the birds are changed from the growing mash to a breeder mash.

The birds should consume about equal weights of mash and grain. If they tend to eat too much grain, the grain hoppers can be kept open only part of each day.

IV. Ducks; Geese

1598. Ducks.—When ducks are raised for the production of meat, the ducklings are generally marketed at 10 to 12 weeks of age, weighing 5 to 6 lbs. A sandy soil is best for duck farms, and the ducks should have access to a body of water, if possible. A somewhat isolated location is desirable, as large flocks of ducks are noisy, and the pens may have an unpleasant smell in summer.

1599. Feeding breeding ducks.—The older method of feeding breeding ducks was to feed a wet mash in the morning and in the afternoon, and also to feed a mixture of grains in addition. This method has been largely replaced by the labor-saving method of feeding dry pellets in hoppers, with grain fed in hoppers in addition.

The feed hoppers are kept open not more than an hour in the morning and 2 hours in late afternoon. About 90 lbs. of pellets are fed to each 10 lbs. of grain during the laying season, and 50 lbs. of pellets to each 20 lbs. of grain during the rest of the year.

A popular mash for the mash-feeding method has the following ingredients per ton of feed:[50] 425 lbs. ground yellow corn, 300 lbs. wheat bran, 200 lbs. wheat standard middlings, 300 lbs. wheat red dog, 200 lbs. low-fiber ground oats, 150 lbs. soybean oil meal, 75 lbs. meat scrap, 120 lbs. alfalfa meal, 150 lbs. dried skimmilk, 70 lbs. pulverized limestone, and 10 lbs. salt. The mash should have about 18 per cent total protein and should contain 650 A.O.A.C. chick units of vitamin D per pound. If green feed is available, the alfalfa meal may be omitted.

The ducks should eat about twice as great a weight of mash as of grain. They should be provided with oyster shell or high-grade limestone grit, and also with granite grit and screened gravel. Good pasture is very desirable

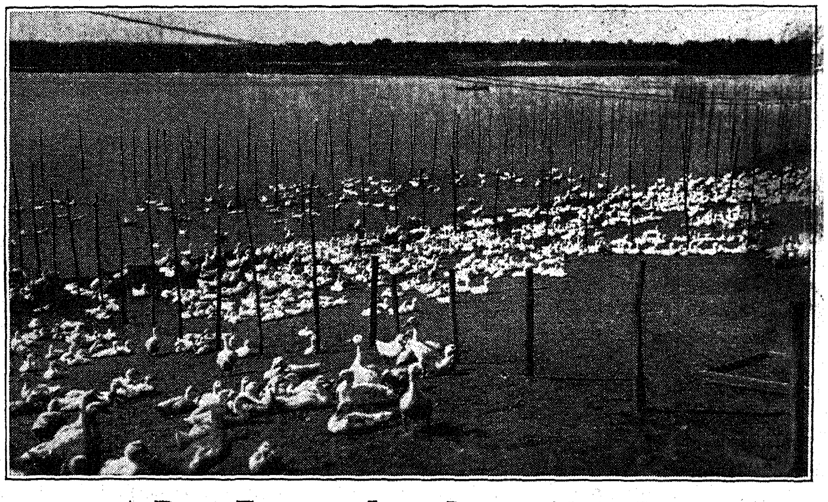
for raising breeding ducks, if it can be provided.

1600. Feeding ducklings.—As in the case of breeding ducks, the feeding of dry pellets in hoppers has largely replaced the feeding of wet mash on commercial duck farms.

Much less information is available concerning definite nutrient requirements of ducks than for chickens, or even turkeys. The special committee of the National Research Council gives the following estimates of certain nutrient requirements in rations for ducklings, per pound of feed: Total protein, 17 per cent; vitamin D, 100 International Chick Units; riboflavin, 1.8 milligrams; pantothenic acid, 5.0 milligrams; niacin, 25.0 milligrams; and pyridoxine, 7.2 milligrams.[29]

A bowed-leg disorder in ducklings raised on wire mesh floors has been found in New York studies to be due apparently to a niacin deficiency.[51] This was prevented by adding 10 milligrams of synthetic niacin per pound of ration, or else 5.0 to 7.5 per cent of brewers' dried yeast, which is rich in niacin. Because of these results, the amount of niacin previously stated for ducklings is twice as high as for chicks.

In the pellet-feeding method, the ducklings have access at all times to dry pellets, fed in hoppers, and to water. No grain is fed separately. At first "starting pellets" are fed, and when the ducklings are 2 weeks old, "duck grower" pellets are used. For the final 2 weeks of fattening, these are replaced by fattening pellets.



A Duck Farm on Long Island, New York

Many large-scale duck farms are located on Long Island, where the conditions are very favorable for duck production. (From Hurd, New York State College of Agriculture, Cornell University, New York.)

In the older method the ducklings are raised on a wet mash which is fed 4 or 5 times a day during the first week and then 3 or 4 times daily. Any feed left should be removed after each feeding. No grain is fed, but chopped fresh green feed or cooked vegetables are sometimes supplied.

A suitable mash for the first 6 weeks contains the following ingredients per ton:[50] 690 lbs. ground yellow corn, 300 lbs. wheat bran, 200 lbs. wheat standard middlings, 300 lbs. wheat red dog, 150 lbs. soybean oil meal, 100 lbs. meat scrap, 120 lbs. alfalfa meal, 100 lbs. dried skimmilk, 30 lbs. pulverized limestone, and 10 lbs. salt. After the ducklings are 6 weeks old, the amount of meat

scrap may be reduced to 75 lbs., the alfalfa meal to 100 lbs., and the dried skimmilk to 50 lbs., while the ground corn is increased to 785 lbs.

An antibiotic feed supplement apparently has very much less effect upon ducklings than in the case of poults or chicks.[52]

1601. Geese.—Geese are generally raised where they can have good range or pasture, and where the mature geese pick up most of their living, except during the winter. Geese do not do well in confinement. When pasture is no longer available, the geese should have such roughage as vegetables, alfalfa or other legume hay, silage, or chopped corn stover. Enough grain, such as oats and corn, wheat or barley should be fed to keep the geese in thrifty condition. Before the laying season starts, the amount of grain should be increased and a mash should be fed once a day. A duck or hen mash is satisfactory. Grit and oyster shell should be supplied at least when the geese are laying, and preferably at all times. Water for drinking should always be provided.

The goslings may be fed a chick or duckling mash in wet form, or they can be started on stale bread soaked in milk or water, or on such a mash as 4 parts of ground corn and 1 part of wheat middlings. Plenty of green feed should always be supplied. After 2 to 3 weeks, the goslings will not need any mash if they have plenty of grass or other good pasture.

Differing from the results with ducklings, an antibiotic feed supplement appreciably increases the rate of growth of goslings.[53]

For about 2 or 3 weeks before the young geese are marketed, they may be fattened by confining them in pens and feeding them liberally. A common ration is one feeding a day of a moist mash (such as two-thirds ground corn and one-third wheat middlings), with two feedings a day of a mixture of corn and other grains.

QUESTIONS

1. What grains are used chiefly for feeding poultry in your region? What is the relative feeding value of these grains?
2. About how much feed is needed daily per 100 hens, at 50 per cent egg production; by hens of the light breeds; by hens of the heavy breeds?
3. Describe the mash-and-scratch-grain method of feeding laying hens.
4. What is the advantage and what is the disadvantage of feeding a limited amount of grain in hoppers, instead of in the litter?
5. Discuss the free-choice method of feeding layers.
6. When is the use of wet mash advantageous?
7. Discuss the advantages and disadvantages of all-mash rations for layers.
8. Discuss the use of artificial light for layers.
9. What are the chief items of expense in producing eggs, and what proportions are they of the total gross cost?
10. What are some of the important points to consider in selecting breeding stock?
11. How should rations for breeding hens differ from rations for the production of market eggs?
12. State the important points in saving eggs for hatching.
13. At what time of year should pullets for egg production ordinarily be hatched?
14. Describe the method of hatching eggs with hens.
15. Describe: (a) The artificial brooding of chicks; (b) brooding chicks with hens.
16. Discuss the nutrient requirements of chicks.
17. State the important points in feeding the chicks.
18. Discuss the raising of pullets and cockerels.
19. Describe the usual method used in broiler production.
20. About how much feed is required per pound of live weight in the production of broilers?
21. How do turkeys rank with other livestock in the efficiency of meat production?
22. Compare the nutrient requirements of young turkeys and of chicks.
23. Describe the 2 systems commonly used in raising turkeys.
24. Discuss the requirements of poults for: (a) Protein and amino acids; (b) energy; (c) minerals; (d) vitamins.
25. What results have been secured from adding an antibiotic feed supplement to rations for poults?

26. What use is sometimes made of hormones in producing market turkeys?
27. State some of the essentials for success in turkey production.
28. Discuss the feeding of: (a) Growing turkeys; (b) breeding turkeys.
29. What 2 methods are used in feeding breeding ducks?
30. Describe the methods of feeding ducklings.
31. What important differences are there in the feeding of geese and chickens?

REFERENCES

1. Botsford, Heuser, and Weaver, N.Y. (Cornell) Exten. Bul. 558.
2. Tomhave and Skoglund, Del. Buls. 235, 238; Mehrhof, Stanton, and Sowell, Fla. Bul. 380; Lampman and Petersen, Id. Bul. 276; Carrick, Ind. Rpt. 1941; Martin and Insko, Ky., Poultry Sci., 13, 1934, p. 380; Upp, Heath, and Johns, La. Rpt. 1943; Vondell, Mass. Buls. 428, 436; Davidson, Mich. Quar. Bul., 20, 1937, No. 2; 22, 1939, No. 2; Sloan, Minn. Farm and Home Sci., 2, 1945, No. 3; Platt and Drago, N.J. Hints to Poultrymen, 29, 1941, No. 1; Berry, New Mex. Press. Bul. 1046; Kelly, Glazener, and Blow, N.C. Res. and Farming, 11, 1952, No. 2; Parker and Barton, N.D. Bul. 345; Kennard and Chamberlin, Ohio Bul. 680; Wilson and Dolacek, S.D. Rpt. 1942; McClary, Bearse, and Miller, Western Wash. Rpt. 1942; Lee, Scholes, and Henry, Poultry Sci., 23, 1944, pp. 360–370; 28, 1949, pp. 10–13.
3. Kennard and Chamberlin, Ohio Bimo. Buls. 201, 210, 214, 219, 222, 230, 243; Kennard and Chamberlin, Ohio Farm and Home Res. No. 248.
4. Goodearl, N.D. Bul. 301.
5. Ore. Bul. 401.
6. Hill, N.Y., Cornell Feed Service, No. 41.
7. Summarized by Heuser, Feeding Poultry, 2nd Ed., 1955, pp. 299–303; see also: Hill, N.Y., Cornell Feed Service, No. 41.
8. Skoglund and Tomhave, Del. Bul. 273; Moore and Mehrhof, Fla. Bul. 420; Bice and Tower, Hawaii, Cir. 12; Carrick, Ind. Rpts. 1938, 1940; Mueller, Avery, Smith, and Clegg, Kan., Poultry Sci., 30, 1951, pp. 679–686; Md. Rpt. 1942; Hall, Andrews, and Bruckner, N.Y. Farm Res., 16, 1950, No. 3; N.C. Rpt. 1943; Parker, N.D. Bimo. Bul., 8, 1946, No. 4; Penquite, Okla. Rpt. 1936–1938; Callenbach, Nicholas, and Murphy, Penn. Bul. 461; Nicholas, Callenbach, and Murphy, Penn. Bul. 462; Alder, Utah Farm and Home Sci., 4, 1943, No. 1; Dobie, Carver, and Roberts, Wash. Bul. 471; Hammond and Titus, U.S.D.A., Poultry Sci., 20, 1941, pp. 507–513.
9. Dakin, Ohio, Poultry Sci., 13, 1934, p. 317; Callenbach, Nicholas, and Murphy, Penn. Bul. 455; Whetham, Jour. Agr. Sci., England, 23, 1933, pp. 383–418; Bissonett, Poultry Sci., 12, 1933, p. 396.
10. Moore, Pfahler, and Card, Mich. Quar. Bul., 17, 1935, pp. 197–203; see also: Insko, Lowry, and Caldwell, Ky. Bul. 560; Heath, Hathaway, Upp, and Woodward, La. Rpt. 1951; Anderson and McNall, Wis. Bul. 453.
11. Carpenter, N.Y. (Cornell) Buls. 896, 897; Kearl, N.Y. (Cornell) Buls, 864, 865; see also: Embleton, Ariz. Bul. 208; Wilcox and Card, Ill. Bul. 486; Oberholtzer, Ind. Bul. 486; Hoecker, Kan. Bul. 308; Heath, Woodward, Hathaway, and Upp, La. Rpt. 1952; Dow, Me. Bul. 412; Wright, Mich. Spec. Bul. 294; Abell, N.H. Cir. 75; Hawthorne and Miller, Penn. Bul. 511; Plaxico, Va. Bul. 438.
12. Carpenter, N.Y. (Cornell) Bul. 897.
13. Carpenter, N.Y. (Cornell) Bul. 896.
14. Pickler, N.Y. (Cornell) Bul. 859.
15. Kennard and Chamberlin, Ohio Bul. 516.
16. For summaries of the experiments to determine the effects of various factors on hatchability, see: Landauer, Conn. (Storrs) Bul. 262, revised; Heuser, Feeding Poultry, 2nd Ed., 1955; Ewing, Poultry Nutrition, 4th Ed., 1951.
17. Lerner and Gunns, Cal., Poultry Sci., 31, 1952, pp. 537–544; Skoglund, Del. Bul. 276; Petersen and Lampman, Id. Bul. 276; Olsen and Haynes, U.S.D.A., Poultry Sci., 28, 1949, pp. 198–201.
18. Darrah, N.Y. (Cornell) Rpt. 1950.
19. Wilgus and Adler, Colo., Poultry Sci., 33, 1954, pp. 460–471; Stephenson, Utah Science, 11, 1950, No. 4; Meshew, Wyo., Poultry Sci., 28, 1949, pp. 87–97.
20. For further information on brooding [illegible] see: Jull and Lee, U.S.D.A. Farmers' Bul. 1538; Hurd, N.Y. (Cornell) Exten. Bul. 153; Barott and Pringle, U.S.D.A., Poultry Sci., 28, 1949, pp. 450–456; Barott and Pringle, U.S.D.A., Jour. Nutr., 41, 1950, pp. 25–30.
21. Parker and Cook, N.D. Bimo. Bul. 8, 1945, No. 1.
22. Heuser, Feeding Poultry, 2nd Ed., 1955, p. 366.
23. Seeger and Tomhave, Del. Bul. 251; Smyth, Me. Bul. 438; Callenbach, Penn. Bul. 475; Berg, Bearse, and Miller, Wash., Poultry Sci., 24, 1945, pp. 122–125; Cunningham and Clark, West Va. Bul. 317; Clark and Cunningham, West Va. Cir. 81; Peterson, Poultry Sci., 23, 1944, pp. 101–104.
24. Sunde, Cravens, Bird, and Halpin, Wis., Poultry Sci., 33, 1954, pp. 779–784.
25. Milby and Sherwood, Poultry Sci., 32, 1953, p. 916; see also: Alp, Hoard's Dairyman, March 10, 1954.
26. Heuser, Norris, and Bruckner, N.Y. (Cornell) Bul. 823; Kennard and Chamberlin, Ohio Bimo. Buls. 228, 233; Kennard and Chamberlin, Ohio Farm and Home Research, No. 248; see also: Davidson, Rather, and Card, Mich. Quar. Bul., 25, 1943, No. 4; Platt and Stover, N.J. Bul. 716.
27. U.S.D.A., Crops and Markets, 1955 Edition.
28. Johnson and Smith, Ark. Bul. 443; Hoffman and Tomhave, Del. Bul. 210; Miss. Rpts. 65, 66.
29. Bird, Almquist, Cravens, Hill, and McGinnis, Nutrient Requirements for Poultry, National Res. Council Publication 301, revised 1954.
30. For detailed discussions concerning the nutritive requirements of turkeys, see: Heuser, Feeding Poultry, 2nd Ed., 1955; Ewing, Poultry Nutrition, 4th Ed., 1951.
31. Baldini, Rosenberg, and Waddell, Poultry Sci., 33, 1954, pp. 539–543; Baldini and Rosenberg, Poultry Sci., 33, 1954, p. 1041; see also: Klain, Hill, and Slinger, Canada, Poultry Sci., 33, 1954, pp. 1280–1282.
32. Md. Bul. A-78; Thornton, Schaible, Davidson, and Libby, Mich. Quar. Bul., 17, 1955, No. 3; Couch, Texas, Feed Age, October, 1953;

Saxena and McGinnis, Wash. Stas. Cir. 197; Pepper and Slinger, Canada, Poultry Sci., 34, 1955, pp. 957–962.

33. Kratzer, Williams, and Marshall, Cal., Poultry Sci., 29, 1950, pp. 285–292; German, Schweigert, Sherwood, and James, Texas, Poultry Sci., 28, 1949, pp. 165–167.

34. Petersen, Lampman, Scrivner, and Wiese, Id. Bul. 280; Briggs and Pilkey, Minn. Farm and Home Sci., 8, 1951, No. 3; Scott, N.Y. Farm Res., 15, 1949, No. 4; Lockhart and Thayer, Okla., Poultry Sci., 34, 1955, p. 34; Blaylock et al., Wash., Poultry Sci., 33, 1954, p. 867; Almquist and Merritt, Poultry Sci., 33, 1954, pp. 434–435.

35. Dymsza, Boucher, and McCartney, Penn., Poultry Sci., 33, 1954, pp. 1159–1163.

36. Alder, Utah Mimeo. Series No. 323.

37. Texas Rpt. 1946.

38. Boucher, Penn., Jour. Nutr., 27, 1944, p. 403; McGinnis and Evans, Wash., Poultry Sci., 25, 1946, p. 521; Bird, U.S.D.A., Jour. Nutr., 27, 1944, p. 377; Sanford and Jukes, Poultry Sci., 23, 1944, p. 221.

39. Slinger, Pepper, and Evans, Canada, Poultry Sci., 34, 1955, p. 48.

40. Sherwood and Sloan, Minn., Poultry Sci., 32, 1953, p. 923; Scott, N.Y., Poultry Sci., 30, 1951, pp. 846–855; Hunt and McGinnis, Wash., Poultry Sci., 31, 1952, p. 921; Hixson and Rosner, Poultry Sci., 33, 1954, pp. 66–68.

41. Scott, N.Y., Poultry Sci., 32, 1953, pp. 670–677.

42. Hunt and Blaylock, Wash., Poultry Sci., 32, 1953, p. 906.

43. Roberts, Ind. Rpt. 1952; Davis and Briggs, Minn., Poultry Sci., 30, 1951, pp. 767–771; Williams and Hill, Miss., Poultry Sci., 31, 1952, pp. 769–772; Miss. Rpt. 1953; Scott and Jensen, N.Y., Poultry Sci., 31, 1952, pp. 986–993; Harper and Babcock, Ore., Poultry Sci., 32, 1953, pp. 179–180; Atkinson, Boucher, and Callenbach, Penn., Poultry Sci., 33, 1954, pp. 332–344; Morgan and Willimon, S.C. Rpt. 1951; Patrick, Tenn., Poultry Sci., 30, 1951, pp. 549–551; Couch and Atkinson, Texas Prog. Rpt. 1256; Atkinson and Couch, Texas, Poultry Sci., 31, 1952, pp. 115–118; Atkinson, Reid, Quisenberry, and Couch, Texas, Jour. Nutr., 51, 1953, pp. 53–64; Reid, Elam, and Couch, Texas, Poultry Sci., 33, 1954, pp. 307–309; McGinnis, Stern, Wilcox, and Carver, Wash., Poultry Sci., 30, 1951, pp. 492–496; McGinnis, Wash., Poultry Sci., 30, 1951, p. 924; Saxena et al., Wash., Poultry Sci., 32, 1953, pp. 721–726, 788–791; Swickard, Harkin, and Marsden, U.S.D.A., Poultry Sci., 32, 1953, pp. 726–729; Branion and Hill, Canada, Poultry Sci., 30, 1951, pp. 793–798; Slinger, Morphet, Gartley, and Arthur, Canada, Poultry Sci., 31, 1952, pp. 881–887; Slinger and Pepper, Canada, Poultry Sci., 33, 1954, pp. 746–753; Slinger, Morphet, Hunt, and Pepper, Canada, Poultry Sci., 33, 1954, pp. 944–951; MacGregor, Blakely, and Anderson, Canada, Poultry Sci., 33, 1954, pp. 36–38; Almquist and Merritt, Poultry Sci., 32, 1953, pp. 878–880; Stokstad and Jukes, Poultry Sci., 29, 1950, pp. 611–612; White-Stevens and Stokstad, Poultry Sci., 33, 1954, p. 1086.

44. Carlson, S.D. Farm and Home Res., 2, 1951, No. 2; Carlson, Jones, Kohlmeyer, and Moxon, S.D., Poultry Sci., 32, 1953, pp. 984–989; Atkinson and Couch, Texas, Poultry Sci., 30, 1951, pp. 905–906; Slinger, Morphet, Hunt, and Pepper, Canada, Poultry Sci., 32, 1953, pp. 660–669; Slinger, Pepper, Morphet, and Evans, Canada, Poultry Sci., 32, 1953, pp. 754–762.

45. McGinnis, Stern, Wilcox, and Carver, Wash., Poultry Sci., 30, 1951, pp. 492–496; Anderson, Cunningham, and Slinger, Canada, Jour. Nutr., 48, 1952, pp. 539–552; Pepper and Slinger, Canada, Poultry Sci., 34, 1955, pp. 928–934; Morehouse, Poultry Sci., 28, 1949, pp. 375–384.

46. Lane, Quisenberry, Couch, and Brown, Texas, Poultry Sci., 30, 1951, p. 921; Stadelman, Wash., Poultry Sci., 30, 1951, p. 931; Stadelman, Kruiswyk, and Dockstader, Wash., Poultry Sci., 31, 1952, pp. 182–184; Adams et al., Wis. Bul. 498; Robblee, Morrison, and Clandinin, Canada, Poultry Sci., 30, 1951, pp. 772–774; Almquist, Poultry Sci., 31, 1952, pp. 747–748.

47. Largely adapted from Jull, Rules for Reducing Turkey Losses, National Turkey Federation, 1946.

48. Kennard and Chamberlin, Ohio, Feedstuffs, July 6, 1940; Couch, German, James, and Sherwood, Texas, Poultry Sci., 26, 1947, pp. 176–179.

49. Heuser, Feeding Poultry, 2nd Ed., 1955.

50. Hurd and Hilbert, N.Y. (Cornell) Exten. Bul. 345.

51. Heuser and Scott, N.Y., Poultry Sci., 32, 1953, pp. 137–143.

52. Branion, Anderson, and Hill, Canada, Poultry Sci., 32, 1953, pp. 335–347.

53. Branion and Hill, Canada, Poultry Sci., 31, 1952, pp. 1100–1102; Slinger, Snyder, and Pepper, Canada, Poultry Sci., 32, 1953, pp. 396–400.

APPENDIX

Table I. Average Composition of American Feeds; Digestible Nutrients; Mineral and Fertilizing Constituents; Digestion Coefficients

New compilation of composition and digestibility of feeds.—In order to present as accurate and complete information as possible concerning the composition of all our important feeds, a new and exhaustive compilation of available data has been made for this volume.

The first compilation of analyses of American feeds made by the author and associates was published in 1915 in the [illegible] edition of *Feeds and Feeding*. This was superseded by a new compilation published in 1936 in the 20th edition of *Feeds and Feeding*. In turn, this was replaced by another new compilation published in 1948 in the 21st edition of the book. The work on this one table has now extended over a period of more than 40 years.

The great mass of data utilized in the preparation of this table is evident from the fact that time equivalent to one person working steadily for more than twelve years has been required in the compilation and averaging of the data.

The author wishes to acknowledge the invaluable help rendered by his wife, Elsie B. Morrison, and by his son, Dr. Spencer H. Morrison, in the compilation of these and other data. His son, Roger B. Morrison, also aided in previous compilations.

Sources of data.—These compilations include analyses published in the bulletins and reports of the State Experiment Stations, the United States Department of Agriculture, the Departments of Agriculture of certain states, and various scientific journals. Data for a few feeds, for which American analyses are not available, have been taken from foreign sources.

Recent analyses of some feeding stuffs show that the composition has changed since the previous compilations were published. In all such cases, the older analyses have been discarded, and the new averages are based on only the recent analyses.

In certain feeds, the change in composition has been due to the general introduction of new varieties. The most striking example of this is dent corn. The present hybrid varieties, which are now generally grown, are decidedly lower in protein than the older open-pollinated varieties. (682)

In the case of certain by-product feeds, the composition has been changed appreciably by modifications in the manufacturing processes. Thus, the fat content of various oil meals produced by the expeller process or by the hydraulic process is lower than some years ago.

Where information is available, separate averages are given for the various grades of a feeding stuff. Thus, separate averages are given for the most important forage crops cut at different stages of maturity; for hay of various qualities; for high-grade and lower-grade concentrates of the same name; etc. In this table the scientific names of the various plants are not stated where they are given in the discussion of the particular feeds in the body of the text.

Cooperation with National Research Council.—The Committee on Feed Composition of the National Research Council, of which the author is a member, undertook some years ago a compilation of the data concerning the composition of American concentrates. These data were secured chiefly from feed manufacturers who cooperated in the undertaking.

In order to present the most comprehensive data possible, unpublished

data which were compiled by the Committee were combined with data compiled by the author and associates. It was planned that the complete combined data would be published by the Committee and also in *Feeds and Feeding*.

Unfortunately, the Committee was unable to finish the compilation and to publish it in complete form. This was because of the sudden death of Mr. Frank E. James, the secretary of the Committee, who had compiled most of the data. Also, funds were insufficient to complete the undertaking, except for the detailed study of the composition of dent corn, which has been mentioned previously. (**682**)

The Committee has recently been able to undertake another compilation of the composition of American feeds, because of funds furnished by the United States Department of Agriculture. The author has again made available to Mr. Donald F. Miller, technical secretary of the Committee, data which has been compiled for this 22nd edition of *Feeds and Feeding*.

A preliminary report on the composition of concentrate by-products has recently been issued by the National Research Council, and other reports are in preparation. The author has used data from the report on concentrate by-product feeds in the compilation of Appendix Tables IV and V.

Dry matter, digestible protein and total digestible nutrients.—The figures for dry matter, digestible protein, and total digestible nutrients are printed in bold-face type and are given first in this table, since these are the figures commonly used in computing balanced rations. Explanations of the methods of computing digestible protein, total digestible nutrients, and nutritive ratios are given in Chapter III. (**63, 65**)

The figures for digestible nutrients have been computed by means of the digestion coefficients obtained in experiments with cattle and sheep. However, these figures may also be used in computing rations for horses and swine and according to the feeding standards given in Appendix Table III. (**62**) Where no digestion coefficients are available for a feed, or such data seem unreliable, the digestion coefficients for a similar feed have been used and that fact is indicated by an asterisk (*).

Digestion coefficients.—Where reliable digestion coefficients are available for a feed, the average digestion coefficients are given on the right-hand page of the table, opposite the average analysis of the feed, which is shown on the left-hand page. These averages are for the experiments conducted with cattle and sheep. Relatively few digestion experiments have been conducted with other livestock.

The author and associates have brought down to date for this volume their compilation of the digestion coefficients secured in experiments conducted in this country. For some feeds [illegible] data on digestibility are lacking, or [illegible] inadequate in amount. In these cases the author has been aided by a comprehensive compilation made by Dr. B. H. Schneider of digestion coefficients secured in experiments not only in this country but also in other countries. This compilation, entitled *Feeds of the World, Their Digestibility and Composition*, was published by West Virginia University in 1947.

For a considerable number of feeds, the digestion coefficients given in *Feeds and Feeding* are taken, with Professor Schneider's permission, from his compilation. Such cases are indicated by a dagger (†) after the "number of trials."

Where Dr. Schneider's data are used in this table, the coefficients obtained in experiments with cattle and with sheep have been combined. These are given separately in Professor Schneider's publication. The coefficients for cattle and sheep have been combined in this table because experiments have shown there is less difference in digestibility of most feeds by cattle and by sheep than there is in digestibility by individual animals of the same species. (**106**)

In the compilation of American digestion coefficients made by the author and associates, some of the older data have been discarded. These experiments

were conducted many years ago, before the discoveries had been made concerning the importance of vitamins and minerals in animal nutrition. Perhaps for this reason, in some cases these old digestion coefficients do not agree with our present knowledge concerning the actual values of certain feeds for livestock.

Mineral and fertilizing constituents.—Detailed information is given in Appendix Table IV concerning the mineral content of the important feeds. For convenience in computing rations, the percentages of calcium and of phosphorus in various feeds are also given in Appendix Table I, so far as data are available.

The average percentages of nitrogen and potassium are also given, so that the fertilizing value or the manurial value of the various feeds can be readily determined. (988)

Variations in composition.—In using this table it must be borne in mind that individual lots of any particular feeding stuff may differ in composition from the average, as has been shown previously. (96–100) In the case of roughages, the variations are apt to be especially large in the content of calcium and of phosphorus. Also, much less information is available concerning the mineral content of various feeds than concerning the amounts of other nutrients they contain. The figures for calcium and phosphorus therefore merely indicate the approximate percentages that are present in the different feeds when produced on soil reasonably well supplied with these minerals.

TABLE I. Average composition and digestible nutrients

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition					No. of anal.
					Protein	Fat	Fiber	N-free extract	Mineral matter	
Dry Roughages	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Alfalfa hay, all analyses	90.5	10.9	50.7	3.7	15.3	1.9	28.6	36.7	8.0	1,288
Alfalfa hay, very leafy (less than 25% fiber)	90.5	12.8	52.7	3.1	17.5	2.4	22.7	39.5	8.4	219
Alfalfa hay, leafy (25–28% fiber)	90.5	11.7	51.2	3.4	16.0	2.1	27.2	36.8	8.4	294
Alfalfa hay, good (28–31% fiber)	90.5	10.2	50.3	3.9	14.6	1.8	29.6	36.5	8.0	323
Alfalfa hay, fair (31–34% fiber)	90.5	9.7	50.3	4.2	13.7	1.7	31.8	36.0	7.3	147
Alfalfa hay, stemmy (over 34% fiber) ..	90.5	8.2	46.3	4.6	12.3	1.4	35.9	33.4	7.5	132
Alfalfa hay, before bloom	90.5	13.0	52.1	3.0	18.6	2.6	23.7	37.0	8.6	23
Alfalfa hay, 1/10 to 1/2 bloom	90.5	11.2	51.4	3.6	15.4	1.6	28.5	36.7	8.3	68
Alfalfa hay, 3/4 to full bloom	90.5	10.2	50.3	3.9	14.1	1.9	30.2	36.3	8.0	[illegible]
Alfalfa hay, past bloom	90.5	9.3	47.7	4.1	12.9	2.1	31.8	36.3	7.4	11
Alfalfa hay, barn-dried, good	89.3	13.1	50.4	2.8	17.7	1.8	26.8	36.2	6.8	43
Alfalfa hay, brown ...	87.9	9.2	44.0	3.8	17.3	1.6	24.5	35.1	9.4	3
Alfalfa leaf meal, good *	92.3	16.0	56.7	2.5	21.1	2.8	16.6	39.7	12.1	212
Alfalfa leaf meal, dehydrated *	92.7	16.0	57.2	2.6	21.1	3.3	17.5	39.3	11.5	14
Alfalfa leaf meal, high in fiber *	91.9	14.5	52.9	2.6	19.8	2.9	20.8	37.8	10.6	74
Alfalfa leaves	89.4	17.3	57.7	2.3	22.2	2.8	13.9	40.6	9.9	57
Alfalfa meal, dehydrated, all analyses	92.7	12.4	54.4	3.4	17.7	2.5	24.0	38.4	10.1	535
Alfalfa meal, dehydrated, 20% protein grade *	92.2	14.7	56.1	2.8	20.2	2.8	20.0	38.3	10.9	60
Alfalfa meal, dehydrated, 20% protein guarantee, fat added * ...	93.0	16.6	56.9	2.4	22.7	3.5	18.5	37.1	11.2	7
Alfalfa meal, 17% protein guarantee * ...	92.7	12.3	54.2	3.4	17.6	2.4	24.6	38.0	10.1	74
Alfalfa meal, dehydrated, 17% protein guarantee *	92.8	12.3	54.4	3.4	17.5	2.5	24.5	38.3	10.0	449
Alfalfa meal, dehydrated, 17% protein guarantee, fat added *	94.2	12.5	56.3	3.5	17.9	4.2	24.3	38.3	9.5	12
Alfalfa meal, 15% protein guarantee	91.6	10.8	52.8	3.9	15.0	2.0	27.9	37.9	8.8	61
Alfalfa meal, dehydrated, 15% protein guarantee *	92.6	11.1	53.2	3.8	15.9	2.5	25.5	39.6	9.1	22
Alfalfa meal, 13% protein guarantee *	90.7	10.0	49.7	4.0	14.3	1.7	29.5	36.1	9.1	205
Alfalfa pellets, 17% protein guarantee * ...	90.6	12.5	53.5	3.3	17.8	2.9	24.1	36.5	9.3	5
Alfalfa stem meal * ...	91.0	6.1	42.0	5.9	11.9	1.4	35.2	35.1	7.4	75

TABLE I. Average composition and digestible nutrients

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Alfalfa hay, all analyses	1.47	0.24	2.45	1.97	71	30	45	70	587
Alfalfa hay, very leafy (less than 25% fiber)	1.61	0.24	2.80	1.95	73	31	45	71	79
Alfalfa hay, leafy (25–28% fiber)	1.31	0.24	2.56	1.99	73	30	44	71	118
Alfalfa hay, good (28–31% fiber)	1.22	0.22	2.34	1.97	70	31	46	69	114
Alfalfa hay, fair (31–34% fiber)	1.13	0.20	2.19	1.78	71	27	45	70	49
Alfalfa hay, stemmy (over 34% fiber)	1.07	0.19	1.97	1.68	67	18	45	64	55 †
Alfalfa hay, before bloom	2.22	0.33	2.98	2.14	70	23	53	68	32
Alfalfa hay, 1/10 to 1/2 bloom	1.47	0.24	2.46	1.97	73	27	46	71	50
Alfalfa hay, 3/4 to full bloom	1.22	0.22	2.26	1.97	72	35	44	70	17
Alfalfa hay, past bloom	1.10	0.20	2.06	1.73	72	28	46	62	6 †
Alfalfa hay, barn-dried, good	..	..	2.83	..	74	18	58	58	4
Alfalfa hay, brown	1.37	0.26	2.77	..	53	1	46	67	7
Alfalfa leaf meal, good	1.69	0.25	3.38	..	..	..	..	..	..
Alfalfa leaf meal, dehydrated	..	..	3.38	..	..	..	..	..	..
Alfalfa leaf meal, high in fiber	..	..	3.17	..	..	..	..	..	..
Alfalfa leaves	2.22	0.24	3.55	2.06	78	27	56	76	18 †
Alfalfa meal, dehydrated, all analyses	1.60	0.26	2.83	..	70	44	48	73	50
Alfalfa meal, dehydrated, 20% protein grade	1.74	0.28	3.23	..	..	..	..	..	..
Alfalfa meal, dehydrated 20% protein guarantee, fat added	..	..	3.63	..	..	..	..	..	..
Alfalfa meal, 17% protein guarantee	1.58	0.26	2.82	..	..	..	..	..	..
Alfalfa meal, dehydrated, 17% protein guarantee	1.58	0.26	2.80	..	..	..	..	..	..
Alfalfa meal, dehydrated, 17% protein guarantee, fat added	..	..	2.86	..	..	..	..	..	..
Alfalfa meal, 15% protein guarantee	..	..	2.40	..	72	36	47	72	15 †
Alfalfa meal, dehydrated, 15% protein guarantee	1.38	0.25	2.54	2.14	..	..	..	..	..
Alfalfa meal, 13% protein guarantee	..	..	2.29	..	..	..	..	..	..
Alfalfa pellets, 17% protein guarantee	..	..	2.85	..	..	..	..	..	..
Alfalfa stem meal	..	..	1.90	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. pro- tein	Total dig. nutri- ents	Nutri- tive ratio	Average total composition: Pro- tein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Alfalfa stems	**89.1**	**5.1**	**41.2**	7.1	10.0	1.1	37.6	34.3	6.1	54
Alfalfa straw *	**92.7**	**4.7**	**42.6**	8.1	9.2	1.5	40.6	34.6	6.8	5
Alfalfa and bromegrass hay	**89.2**	**7.6**	**47.9**	5.3	11.8	2.0	32.5	36.7	6.2	12
Alfalfa and grass hay *	**89.6**	**7.7**	**48.3**	5.3	12.0	1.5	30.4	39.5	6.2	15
Alfalfa and timothy hay *	**89.6**	**7.9**	**48.2**	5.1	12.3	2.1	31.1	37.7	6.4	4
Alfilaria, dry (*Erodium cicutarium*) *	**89.2**	**7.7**	**48.4**	5.3	10.9	2.9	23.4	40.2	11.8	8
Alfilaria, dry, mature *	**89.0**	**1.8**	**41.7**	22.2	3.5	1.5	31.4	44.1	[illegible]	1
Atlas sorghum fodder *	**75.1**	**2.9**	**45.0**	14.5	5.3	2.3	16.7	45.4	5.4	1
Atlas sorghum stover *	**75.0**	**1.2**	**44.0**	35.7	3.5	1.7	23.2	40.7	[illegible]	6
Barley hay	**90.8**	**4.0**	**51.9**	12.0	7.3	2.0	25.4	49.3	[illegible]	17
Barley straw	**90.0**	**0.7**	**42.2**	59.3	3.7	1.6	37.7	41.0	6.6	97
Bean hay, mung *	**90.3**	**6.5**	**49.8**	6.7	9.7	2.2	24.0	46.6	7.8	2
Bean hay, tepary *	**90.0**	**11.5**	**48.1**	3.2	17.1	2.9	24.8	34.7	[illegible]	1
Bean vines, snap, de-hydr.*	**89.3**	**12.3**	**46.3**	2.8	18.3	1.5	21.4	35.2	12.9	1
Bean pods, field, dry *	**91.8**	**3.5**	**48.7**	12.9	7.1	1.0	34.8	45.0	3.9	3
Bean straw, field	**89.1**	**3.0**	**45.2**	14.1	6.1	1.4	40.1	34.1	7.4	20
Beggarweed hay *	**90.9**	**10.6**	**47.7**	3.5	15.2	2.3	28.4	37.2	7.8	13
Bentgrass hay, Colonial	**88.5**	**2.8**	**49.1**	16.5	6.6	3.0	29.5	42.8	6.6	2
Bermuda grass hay, common, good	**90.5**	**3.6**	**44.2**	11.3	7.1	1.8	25.9	48.7	7.0	22
Bermuda grass hay, Coastal, fertilized with nitrogen	**90.5**	**6.3**	**50.8**	7.1	9.2	2.1	27.8	46.7	4.7	17
Bermuda grass hay, Coastal, no nitrogen fertilizer *	**90.0**	**3.3**	**45.2**	12.7	6.4	1.9	27.6	49.4	4.7	3
Bermuda grass hay, poor *	**90.0**	**2.1**	**40.7**	18.4	5.8	0.9	38.8	37.7	6.8	1
Berseem, or Egyptian clover hay	**90.6**	**9.0**	**51.9**	4.8	13.4	3.1	24.4	38.7	11.0	12
Birdsfoot trefoil hay	**91.2**	**9.8**	**55.0**	4.6	14.2	2.1	27.0	41.9	6.0	4
Black grass hay (*Juncus Gerardi*) *	**89.7**	**5.0**	**55.0**	10.0	7.5	2.5	25.1	47.3	7.3	21
Bluegrass hay, Canada	**89.3**	**2.8**	**53.3**	18.0	6.6	2.3	28.2	46.4	5.8	10
Bluegrass hay, Kentucky, all anal.	**89.4**	**4.8**	**54.8**	10.4	8.2	2.8	29.8	42.1	6.5	25
Bluegrass hay, Kentucky, in seed *	**87.3**	**2.0**	**40.1**	19.1	5.5	2.5	31.0	41.9	6.4	3
Bluegrass hay, native western *	**91.9**	**6.7**	**52.6**	6.9	11.2	3.0	29.8	39.9	8.0	7
Bluejoint hay (*Calamagrostis Canadensis*)	**88.5**	**4.8**	**50.7**	9.6	7.2	2.3	32.9	39.6	6.5	10
Bluestem hay (*Andropogon*, spp.) *	**86.6**	**1.7**	**39.2**	22.1	5.4	2.2	30.2	43.4	5.4	51
Bromegrass hay, smooth, all anal.	**88.8**	**5.3**	**49.3**	8.3	10.4	2.1	28.2	39.9	8.2	126
Bromegrass hay, smooth, before heading *	**89.0**	**9.6**	**55.9**	4.8	14.8	2.0	23.9	38.7	9.6	8

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phos-phorus	Nitro-gen	Potas-sium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Alfalfa stems	0.82	0.17	1.60	2.21	51	48	39	59	18
Alfalfa straw	..	0.13	1.47	..	..	..	..	..	..
Alfalfa and bromegrass hay	0.77	0.20	1.89	1.66	64	29	50	62	9
Alfalfa and grass hay	1.18	0.24	1.92	..	..	..	..	..	..
Alfalfa and timothy hay	0.83	0.20	1.97	..	..	..	..	..	..
Alfilaria, dry (*Erodium [illegible]ium*)	1.57	0.41	1.74	..	..	..	..	..	..
[illegible] dry, mature	..	..	0.56	..	..	..	..	..	..
Atl[illegible]rghum fodder	..	..	0.85	..	..	..	..	..	..
At[illegible]ghum stover	0.29	0.08	0.56	..	..	..	..	..	..
Bar[illegible]ay	0.26	0.23	1.17	1.35	55	47	50	67	22
Barley straw	0.33	0.10	0.59	1.33	19	42	57	45	8 †
Bean hay, mung	..	..	1.55	..	..	..	..	..	..
[illegible] tepary	..	..	2.74	..	..	..	..	..	..
[illegible]s, snap, [illegible]dr.	1.29	0.24	2.93	..	..	..	..	..	..
Bean pods, field, dry	0.78	0.10	1.14	2.02	..	..	..	..	..
Bean straw, field	1.67	0.13	0.98	1.02	49	57	43	68	5
Beggarweed hay	1.05	0.27	2.43	2.32	..	..	..	..	..
Bentgrass hay, Colonial	..	0.18	1.06	1.42	42	30	63	60	4 †
Bermuda grass hay, common, good	0.37	0.19	1.14	1.42	51	44	52	52	11
Bermuda grass hay, Coastal, fertilized with nitrogen	0.27	0.18	1.47	..	69	53	60	54	8
Bermuda grass hay, Coastal, no nitrogen fertilizer	..	..	1.02	..	..	..	..	..	..
Bermuda grass hay, poor	..	..	0.93	..	..	..	..	..	..
Berseem, or Egyptian clover hay	3.27	0.28	2.14	2.05	67	39	49	73	8
Birdsfoot trefoil hay	1.60	0.20	2.27	1.66	69	34	53	70	5
Black grass hay (*Juncus Gerardi*)	..	0.09	1.20	1.56	..	..	..	..	..
Bluegrass hay, Canada	..	0.20	1.06	1.94	43	37	70	62	2
Bluegrass hay, Kentucky, all anal.	0.40	0.27	1.31	1.67	58	50	67	64	14 †
Bluegrass hay, Kentucky, in seed	0.23	0.20	0.88	1.48	..	..	..	..	..
Bluegrass hay, native western	..	..	1.79	..	..	..	..	..	..
Bluejoint hay (*Calamagrostis Canadensis*)	..	..	1.15	..	66	47	60	60	3 †
Bluestem hay (*Andropogon*, spp.)	..	..	0.86	..	..	..	..	..	..
Bromegrass hay, smooth, all anal.	0.42	0.19	1.66	2.26	51	39	59	64	11
Bromegrass hay, smooth, before heading	..	..	2.37	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Bromegrass hay, smooth, before bloom *	90.3	5.6	50.4	8.0	10.9	2.2	28.2	41.1	7.9	5
Bromegrass hay, smooth, in bloom *	87.6	4.5	48.8	9.8	8.8	1.9	31.2	37.9	7.8	4
Bromegrass hay, smooth, after bloom *	94.0	2.1	43.2	19.6	5.9	2.1	31.0	48.4	6.6	4
Broom corn stover *	90.6	0.7	45.5	64.0	3.9	1.8	36.8	42.4	5.7	1
Buckwheat hulls	88.6	0.2	13.9	68.5	3.0	1.0	42.9	40.1	1.6	58
Buckwheat straw *	88.6	1.2	37.5	30.3	4.3	1.0	36.2	38.8	8.3	11
Buffalo grass hay (*Bulbilis dactyloides*)	88.7	3.7	47.7	11.9	6.8	1.8	23.8	46.2	10.1	15
Bunchgrass hay, misc. var. *	91.7	1.8	39.7	21.1	5.8	2.0	30.4	44.1	9.4	12
Cocoa pods, dried *	91.7	3.5	48.9	13.0	7.5	1.3	31.7	44.2	7.0	2
Carpet grass hay *	92.1	3.6	43.6	11.1	7.0	2.2	31.8	40.9	10.2	1
Cat-tail, or tule hay (*Typha angustifolia*) *	90.8	2.6	41.3	14.9	5.8	1.7	30.8	44.3	8.2	2
Cereals, young, dehydr. *	92.8	19.1	56.1	1.9	24.5	4.7	16.1	33.1	14.4	4
Chess, or cheat, hay (*Bromus*, spp.)	91.7	3.7	50.3	12.6	6.9	2.1	29.2	46.1	7.4	12
Clover hay, alsike, all analyses	88.9	8.1	53.2	5.6	12.1	2.1	27.0	39.9	7.8	48
Clover hay, alsike, in bloom	89.0	9.0	53.9	5.0	13.4	3.2	26.9	37.7	7.8	5
Clover hay, Alyce	89.0	6.6	49.4	6.5	10.9	1.6	35.4	35.5	5.6	..
Clover hay, bur.	92.1	13.4	54.4	3.1	18.4	2.9	22.9	37.8	10.1	14
Clover hay, crimson	89.5	9.8	48.9	4.0	14.2	2.2	27.4	37.0	8.7	20
Clover hay, Ladino	89.5	14.2	59.5	3.2	18.5	1.7	21.6	38.4	8.3	8
Clover hay, Ladino, before bloom *	88.4	16.5	58.2	2.5	21.4	1.4	18.6	36.6	10.4	1
Clover, Ladino, and grass hay	88.3	11.3	57.4	4.1	15.9	2.2	21.5	41.7	7.0	12
Clover hay, mammoth red *	88.0	6.7	52.3	6.8	11.7	3.4	29.2	37.0	6.7	19
Clover hay, Persian *	90.0	8.8	50.2	4.7	14.7	1.6	27.7	36.7	9.3	1
Clover hay, red, all analyses	88.3	7.2	51.8	6.2	12.0	2.5	27.1	40.3	6.4	218
Clover hay, red, leafy (less than 25% fiber) *	88.3	9.2	54.5	4.9	13.5	2.9	23.3	41.6	7.0	67
Clover hay, red, good (25 to 31% fiber)	88.3	6.7	52.9	6.9	11.6	2.5	27.3	40.7	6.2	118
Clover hay, red, stemmy (over 31% fiber)	88.3	5.8	49.3	7.5	10.4	2.0	33.7	36.4	5.8	33
Clover hay, red, before bloom	88.1	11.3	60.1	4.3	18.3	3.6	18.0	41.1	7.1	2
Clover hay, red, early to full bloom	88.1	7.9	54.6	5.9	12.5	3.5	26.1	39.7	6.3	48
Clover hay, red, second cutting *	88.1	8.4	54.1	5.4	13.4	2.9	24.5	40.4	6.9	15

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Bromegrass hay, smooth, before bloom	..	..	1.74	..	..	..	..	..	..
Bromegrass hay, smooth, in bloom	..	..	1.41	..	..	..	..	..	..
Bromegrass hay, smooth, after bloom	0.29	0.13	0.94	..	..	..	..	..	..
Broom corn stover	..	..	0.62	..	..	..	..	..	..
Buckwheat hulls	0.26	0.02	0.48	0.27	7	9	8	25	1 †
Buckwheat straw	1.24	0.04	0.69	2.00	..	..	..	..	..
Buffalo grass hay (*Bulbilis dactyloides*)	0.70	0.13	1.09	1.36	54	45	61	60	3
Bunchgrass hay, misc. var.	..	..	0.93	..	..	..	..	..	..
Cocoa pods, dried	..	..	1.20	..	..	..	..	..	..
Carpet grass hay	..	..	1.12	..	..	..	..	..	..
Cat-tail, or tule hay (*Typha angustifolia*)	..	..	0.93	..	..	..	..	..	..
Cereals, young, dehydr.	0.66	0.46	3.92	..	..	..	..	..	..
Chess, or cheat, hay (*Bromus,* spp.)	0.29	0.25	1.10	1.47	54	61	55	60	5
Clover hay, alsike, all analyses	1.15	0.23	1.94	2.44	67	55	54	70	3
Clover hay, alsike, in bloom	1.32	0.25	2.14	2.27	67	55	54	70	3
Clover hay, Alyce	..	..	1.74	..	61	45	50	66	..
Clover hay, bur.	1.32	0.45	2.94	2.96	73	42	53	69	12
Clover hay, crimson	1.23	0.24	2.27	2.79	69	44	47	65	13
Clover hay, Ladino	1.53	0.29	2.96	2.17	77	22	67	78	6
Clover hay, Ladino, before bloom	..	..	3.42	..	..	..	..	..	..
Clover, Ladino, and grass hay	0.87	0.19	2.54	1.70	71	39	64	73	7
Clover hay, mammoth red	..	0.24	1.87	..	..	..	..	..	..
Clover hay, Persian	1.49	0.21	2.35	..	..	..	..	..	..
Clover hay, red, all analyses	1.28	0.20	1.92	1.65	60	58	53	67	64
Clover hay, red, leafy (less than 25% fiber)	1.47	0.21	2.16	1.36	..	..	..	..	..
Clover hay, red, good (25 to 31% fiber)	1.21	0.21	1.86	1.45	58	57	56	68	26
Clover hay, red, stemmy (Over 31% fiber)	1.12	0.20	1.66	1.11	56	60	41	74	7
Clover hay, red, before bloom	1.57	0.28	2.93	2.26	62	59	57	82	1 †
Clover hay, red, early to full bloom	1.34	0.21	2.00	1.40	63	50	56	71	8
Clover hay, red, second cutting	1.28	0.21	2.14	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Clover hay, sweet, first year	91.8	11.9	50.3	3.2	16.5	2.5	24.6	39.7	8.5	19
Clover hay, sweet, second year	90.7	9.5	47.3	4.0	13.5	1.9	30.2	37.6	7.5	41
Clover hay, white	88.0	10.5	55.6	4.3	14.4	2.4	22.5	40.9	7.8	11
Clover leaves, sweet	92.2	20.5	57.2	1.8	26.6	3.2	9.5	41.9	11.0	10
Clover stems, sweet	92.7	5.6	45.4	7.1	10.6	1.1	38.0	35.6	7.4	10
Clover straw, crimson *	87.7	3.8	40.0	9.5	7.5	1.5	38.8	32.9	7.0	3
Clover and mixed grass hay, high in clover	89.6	5.5	51.8	8.4	9.6	2.7	28.9	42.2	6.2	42
Clover and grass hay, mostly grass	88.0	4.5	49.7	10.0	8.4	1.8	31.0	40.9	5.9	6
Clover and timothy hay, 30 to 50% clover	88.1	4.7	51.0	9.9	8.6	2.2	30.3	41.2	5.8	67
Corn cobs, ground	90.4	0	45.7	..	2.3	0.4	32.1	54.0	1.6	63
Corn fodder, well-eared, very dry (from barn or in arid districts)	91.1	3.8	58.8	14.5	7.8	2.2	27.1	47.6	6.4	59
Corn fodder, medium in water	82.6	3.3	53.9	15.3	6.8	2.1	21.8	46.7	5.2	74
Corn fodder, high in water	60.7	2.4	39.7	15.5	4.8	1.4	16.7	34.2	3.6	23
Corn fodder, drouth-stricken corn, no ears *	85.0	3.8	46.1	11.1	10.8	0.8	25.7	41.2	6.5	1
Corn fodder, sweet corn	87.7	5.9	56.5	8.6	9.2	1.8	26.4	41.3	9.0	6
Corn husks, dried	85.0	0.4	38.9	96.3	3.4	0.9	28.2	49.6	2.9	18
Corn leaves, dried	82.8	3.5	49.8	13.2	7.7	1.9	23.9	42.6	6.7	28
Corn stalks, shanks, and tassles, dried *	82.8	0.8	40.7	49.9	4.7	1.5	28.0	43.3	5.3	20
Corn stover (ears removed), mature, very dry	90.6	2.1	51.9	23.7	5.9	1.6	30.8	46.5	5.8	187
Corn stover, medium in water	80.3	2.0	45.5	21.8	5.8	1.2	27.1	40.7	5.5	109
Corn stover, high in water	59.0	1.4	33.7	23.1	3.9	1.0	20.1	30.2	3.8	247
Corn tops, dried	82.1	2.2	48.3	21.0	5.6	1.5	27.4	42.0	5.6	8
Cotton bolls, dried	90.8	2.3	42.5	17.5	8.7	2.4	30.8	42.0	6.9	16
Cotton leaves, dried *	91.7	6.1	33.4	4.5	15.3	6.8	10.3	43.5	15.8	17
Cotton gin trash *	90.3	1.7	41.9	23.6	6.7	1.5	33.1	41.3	7.7	3
Cottonseed hulls	90.8	0	43.7	..	3.9	0.9	45.0	38.4	2.6	52
Cotton stalks, dried *	92.3	1.7	39.9	22.5	5.7	0.8	43.8	37.8	4.2	14
Cowpea hay, all analyses	90.4	12.3	51.4	3.2	18.6	2.6	23.3	34.6	11.3	41
Cowpea hay, in bloom to early pod	89.9	12.7	52.5	3.1	18.1	3.2	21.8	36.7	10.1	7
Cowpea hay, seed ripe *	90.0	5.7	51.9	8.1	10.1	2.5	29.2	41.8	6.4	3
Cowpea straw *	91.5	2.0	38.3	18.2	6.8	1.2	44.5	33.6	5.4	1
Crabgrass hay	90.3	3.2	47.0	13.7	7.8	2.4	28.7	43.4	8.0	10

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Clover hay, sweet, first year	1.37	0.26	2.64	1.57	72	41	42	65	12
Clover hay, sweet, second year	1.25	0.23	2.16	1.78	70	26	42	64	18
Clover hay, white	1.67	0.28	2.30	..	73	51	61	70	1
Clover leaves, sweet	..	..	4.26	..	77	25	41	74	10
Clover stems, sweet	..	..	1.70	..	53	43	40	66	10
Clover straw, crimson	..	..	1.20	..	..	..	..	..	..
Clover and mixed grass hay, high in clover	0.88	0.21	1.54	1.43	57	46	60	62	75
Clover and grass hay, mostly grass	0.81	0.24	1.34	1.49	54	50	56	63	18
Clover and timothy hay, 30 to 50% clover	0.69	0.16	1.38	1.61	55	54	57	64	76
Corn cobs, ground	0.11	0.04	0.37	0.82	0	25	56	51	9 †
Corn fodder, well-cured, very dry (from barn or in arid districts)	0.27	0.16	1.25	0.90	49	70	69	69	46 †
Corn fodder, medium in water	0.25	0.14	1.09	0.82	..	..	..	..	..
Corn fodder, high in water	0.18	0.11	0.77	0.60	..	..	..	..	..
Corn fodder, drouth-stricken corn, no ears	..	..	1.73	..	..	..	..	..	..
Corn fodder, sweet corn	..	0.17	1.47	0.98	64	74	74	68	6
Corn husks, dried	0.15	0.12	0.54	0.55	13	26	52	47	7
Corn leaves, dried	0.57	0.21	1.23	1.48	45	60	69	64	4
Corn stalks, shanks, and tassles, dried	0.32	0.23	0.75	1.79	..	..	..	..	..
Corn stover (ears removed), mature, very dry	0.54	0.09	0.94	1.49	35	57	66	59	39 †
Corn stover, medium in water	0.48	0.08	0.93	1.32	..	..	..	..	..
Corn stover, high in water	0.35	0.06	0.62	0.97	..	..	..	..	..
Corn tops, dried	..	..	0.90	..	39	67	71	58	4 †
Cotton bolls, dried	0.61	0.09	1.39	3.18	26	64	39	59	4
Cotton leaves, dried	4.58	0.18	2.45	1.36	..	..	..	..	..
Cotton gin trash	..	..	1.07	..	..	..	..	..	..
Cottonseed hulls	0.13	0.06	0.62	0.87	0	78	51	50	33
Cotton stalks, dried	..	..	0.91	..	..	..	..	..	..
Cowpea hay, all analyses	1.37	0.30	2.98	1.66	66	46	51	71	8 †
Cowpea hay, in bloom to early pod	..	..	2.90	..	70	46	48	71	4 †
Cowpea hay, seed ripe	..	..	1.62	..	..	..	..	..	..
Cowpea straw	..	..	1.09	..	..	..	..	..	..
Crabgrass hay	..	..	1.25	..	41	42	60	56	14

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Durra fodder *	89.9	2.4	53.0	21.1	6.4	2.8	24.1	51.4	5.2	3
Emmer hay *	90.0	5.2	43.1	7.3	9.7	2.0	32.8	36.4	9.1	4
Fescue hay, meadow	89.2	3.7	52.7	13.2	7.0	1.9	30.3	43.2	6.8	25
Fescue hay, native western (*Festuca,* spp.) *	90.0	4.5	53.8	11.0	8.5	2.0	31.0	42.8	5.7	13
Fescue, tall, and Ladino clover hay	90.0	12.2	55.7	3.6	15.8	2.0	19.4	42.4	10.4	3
Feterita fodder, very dry	88.0	4.0	50.6	11.7	8.0	2.1	18.7	51.5	7.7	3
Feterita stover *	86.3	1.8	49.3	26.4	5.2	1.7	29.2	41.9	8.3	1
Flat pea hay *	92.3	15.0	55.1	2.7	22.7	3.2	27.7	32.0	6.7	5
Flax plant by-product	92.1	4.5	32.7	6.3	9.3	2.9	33.4	40.4	6.1	74
Flax straw	92.8	5.8	38.1	5.6	7.2	3.2	42.5	32.9	7.0	38
Fowl meadow grass hay *	87.4	4.0	46.6	10.7	8.7	2.3	29.7	39.5	7.2	[illegible]
Furze, dried *	94.5	5.9	33.4	4.7	11.6	2.0	38.5	35.4	7.0	[illegible]
Gama grass hay (*Tripsacum dactyloides*) *	88.2	2.1	39.4	17.8	6.7	1.8	30.4	43.1	6.2	3
Grama grass hay (*Bouteloua,* spp.) *	89.0	1.7	38.8	21.8	5.6	1.5	29.0	44.7	8.2	102
Grass hay, mixed, eastern states, good quality	89.0	3.5	51.7	13.8	7.0	2.5	30.9	43.1	5.5	39
Grass hay, mixed, second cutting *	89.0	7.7	56.2	6.3	12.3	3.3	24.8	41.7	6.9	67
Grass straw	85.0	1.8	40.0	21.2	4.5	2.0	35.0	37.8	5.7	..
Guar hay	93.1	11.5	52.8	3.6	15.3	1.7	21.5	42.5	12.1	2
Harding grass hay *	93.2	4.1	46.7	10.4	6.5	1.6	32.8	45.5	6.8	1
Hegari fodder *	86.3	3.2	52.4	15.4	6.1	1.7	18.2	52.8	7.5	29
Hegari, heads and forage, dehydr.*	90.1	2.8	54.7	18.5	5.4	1.7	17.1	57.7	8.2	6
Hegari stover *	87.0	1.9	48.7	24.6	5.6	1.8	28.0	41.7	9.9	9
Hops, spent, dried	93.8	6.9	30.5	3.4	23.0	3.6	24.5	37.4	5.3	..
Horse bean hay *	91.5	9.0	52.1	4.8	13.4	0.8	22.0	49.8	5.5	1
Horse bean straw	87.9	4.2	44.2	9.5	8.6	1.4	36.4	33.1	8.4	2
Hyacinth bean hay (*Dolichos lablab*)	90.2	9.6	50.7	4.3	14.8	1.4	33.6	33.6	6.8	1
Johnson grass hay	90.2	2.9	50.3	16.3	6.5	2.0	30.5	43.7	7.5	40
June grass hay, western (*Koeleria cristata*) *	88.3	3.2	42.2	12.2	8.1	2.5	30.4	40.5	6.8	17
Kafir fodder, very dry	90.0	4.5	53.6	10.9	8.7	2.6	25.5	44.2	9.0	25
Kafir fodder, high in water	71.7	3.4	45.7	12.4	6.5	2.7	21.6	37.6	3.3	2
Kafir stover, very dry	90.0	1.9	51.3	26.0	5.5	1.8	29.5	44.3	8.9	3
Kafir stover, high in water	72.7	1.3	41.3	30.8	3.8	1.3	23.7	36.6	7.3	4
Koa haole forage, dried *	88.7	9.4	52.5	4.6	12.7	1.9	29.8	39.2	5.1	3
Kochia scoparia hay	90.0	7.2	50.2	6.0	11.4	1.5	23.6	40.7	12.8	5
Kudzu hay *	89.8	10.2	49.3	3.8	15.2	2.3	29.4	36.3	6.6	4
Lespedeza hay, annual, all anal.	90.0	5.6	45.1	7.1	13.1	2.5	26.9	42.2	5.3	96

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Durra fodder	..	..	1.02	..	..	..	..	..	..
Emmer hay	..	..	1.55	..	..	..	..	..	..
Fescue hay, meadow	..	0.20	1.12	1.43	53	52	63	64	22 †
Fescue hay, native western (*Festuca,* spp.)	..	..	1.36	..	..	..	..	..	..
Fescue, tall, and Ladino clover hay	..	..	2.53	..	77	27	63	71	12
Feterita fodder, very dry	0.30	0.21	1.28	..	50	61	66	61	2 †
Feterita stover	..	..	0.83	..	..	..	..	..	..
Flat pea hay	..	0.30	3.63	2.02	..	..	..	..	..
Flax plant by-product	1.22	0.22	0.99	.	48	64	26	38	7 †
[illegible] straw	0.67	0.10	1.15	1.62	81	93	26	44	2
[illegible]adow grass hay	..	..	1.39	..	..	..	..	..	..
[illegible]ried	..	..	1.86	..	..	..	..	..	..
Gama grass hay (*Tripsacum dactyloides*)	..	..	1.07	..	..	..	..	..	..
Grama grass hay (*Bouteloua,* spp.)	0.34	0.18	0.90	..	..	..	..	..	..
Grass hay, mixed, eastern states, good quality	0.48	0.21	1.12	1.20	50	47	61	62	31
Grass hay, mixed, second cutting	0.79	0.31	1.97	1.15	..	..	..	..	..
Grass straw	..	..	0.72	..	40	40	50	50	..
Guar hay	..	..	2.45	..	75	16	45	73	2
Harding grass hay	..	..	1.04	..	..	..	..	..	..
Hegari fodder	0.27	0.16	0.98	..	..	..	..	..	..
Hegari, heads and forage, dehydr.	..	..	0.86	..	..	..	..	..	..
Hegari stover	0.33	0.08	0.90	..	..	..	..	..	..
Hops, spent, dried	..	..	3.68	..	30	47	18	41	9 †
Horse bean hay	..	..	2.14	..	..	..	..	..	..
Horse bean straw	..	..	1.38	..	49	57	43	68	5
Hyacinth bean hay (*Dolichos lablab*)	..	..	2.37	..	65	56	53	64	4 †
Johnson grass hay	0.87	0.26	1.04	1.22	44	46	67	57	9
June grass hay, western (*Koeleria cristata*)	..	..	1.30	..	..	..	..	..	..
Kafir fodder, very dry	0.35	0.18	1.39	1.53	52	59	61	68	12
Kafir fodder, high in water	0.28	0.14	1.04	1.23	..	..	..	..	..
Kafir stover, very dry	0.54	0.09	0.88	..	34	75	67	60	5
Kafir stover, high in water	0.44	0.07	0.61	..	..	..	..	..	..
Koa haole forage, dried	..	..	2.03	..	..	..	..	..	..
Kochia scoparia hay	..	..	1.82	..	63	27	49	75	12
Kudzu hay	2.78	0.21	2.43	..	..	..	..	..	..
Lespedeza hay, annual, all anal.	0.96	0.18	2.10	0.94	43	26	47	60	56

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Lespedeza hay, annual, before bloom	89.1	7.2	49.2	5.8	14.3	2.7	22.7	43.0	6.4	5
Lespedeza hay, annual, in bloom	89.1	6.4	46.4	6.3	13.0	1.8	26.5	42.7	5.1	7
Lespedeza hay, annual, after bloom	89.1	3.6	39.6	10.0	11.5	1.9	32.6	38.6	4.5	11
Lespedeza hay, sericea	89.2	4.1	41.2	9.0	12.4	1.8	27.9	42.3	4.8	20
Lespedeza leaves, ann.*	89.2	9.6	52.1	4.4	17.1	2.9	19.7	43.1	6.4	16
Lespedeza stems, ann.*	89.2	2.6	40.3	14.5	8.3	1.0	38.5	37.7	3.7	16
Lespedeza straw, excellent *	90.0	1.2	44.3	35.9	6.8	2.3	29.2	47.1	4.6	1
Lovegrass hay, weeping	91.2	5.9	51.9	7.8	9.2	2.8	30.9	43.4	4.9	1
Marsh or swamp hay, good quality	90.2	4.1	48.0	10.7	7.6	2.3	28.3	44.3	[illegible]	38
Millet hay, foxtail varieties	87.6	4.9	50.0	9.2	8.2	2.7	25.3	44.7	[illegible]	
Millet hay, hog millet, or proso *	90.3	5.6	50.7	8.1	9.3	2.2	23.9	47.6	7.3	9
Millet hay, Japanese	86.8	5.1	47.3	8.3	8.3	1.6	27.7	40.8	8.4	15
Millet hay, pearl, or cat-tail	87.2	4.2	49.8	10.9	6.7	1.7	33.0	36.8	9.0	6
Millet straw *	90.0	1.5	42.5	27.3	3.8	1.6	37.5	41.6	5.5	6
Milo fodder	88.5	3.0	51.1	16.0	8.0	3.3	21.9	48.4	6.9	16
Milo stover *	91.0	1.1	50.1	44.5	3.2	1.1	29.1	48.1	9.5	1
Mint hay *	88.3	8.5	49.4	4.8	12.7	2.1	20.3	45.6	7.6	1
Mixed hay, good, less than 30% legumes	88.2	4.5	47.8	9.6	8.4	1.8	31.3	41.4	5.3	43
Mixed hay, good, less than 30% legumes, barn-dried	89.2	4.8	48.8	9.2	8.8	1.8	31.4	42.0	5.2	12
Mixed hay, good, more than 30% legumes	90.3	7.2	49.5	5.9	10.3	1.7	31.6	40.9	5.8	7
Mixed hay, excellent, mostly legumes *	91.4	10.0	56.4	4.6	14.3	2.3	24.7	43.5	6.6	3
Mixed hay, cut very early *	90.0	8.4	55.1	5.6	13.3	2.7	25.3	39.4	9.3	10
Napier grass hay *	89.1	3.8	45.4	10.9	8.2	1.8	34.0	34.6	10.5	1
Natal grass hay	90.2	3.1	48.0	14.5	7.4	1.8	36.8	39.2	5.0	..
Native hay, western mt. states, good quality	93.3	5.1	53.8	9.5	8.5	2.2	30.7	44.8	7.1	49
Native hay, western mt. states, mature and weathered	90.0	1.6	36.6	21.9	3.9	1.4	33.6	43.6	7.5	46
Needle grass hay (*Stipa,* spp.) *	88.1	1.4	41.5	28.6	7.2	2.0	30.8	41.9	6.2	38
Oak leaves, live oak, dried	93.8	0	17.0	..	9.3	2.7	29.9	45.3	6.6	2
Oat chaff	91.8	0.9	33.1	35.8	5.9	2.4	25.7	46.3	11.5	4
Oat hay	88.1	4.9	47.3	8.7	8.2	2.7	28.1	42.2	6.9	102
Oat hay, wild (*Avena fatua*) *	92.5	4.0	49.4	11.4	6.6	2.6	32.5	44.0	6.8	11

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Lespedeza hay, annual, before bloom	1.03	0.20	2.29	1.07	50	31	54	65	9
Lespedeza hay, annual, in bloom	1.00	0.19	2.08	0.94	49	31	48	61	27
Lespedeza hay, annual, after bloom	0.90	0.15	1.84	0.82	31	19	43	55	20
Lespedeza hay, sericea	0.92	0.22	1.98	0.98	33	44	37	59	11
Lespedeza leaves, annual	1.30	0.20	2.74	0.92	..	..	..	..	..
Lespedeza stems, annual	0.64	0.13	1.33	0.89	..	..	..	..	..
Lespedeza straw, excellent	..	..	1.09	..	..	..	..	..	..
Love grass hay, weeping	..	..	1.47	..	64	46	65	53	3
Marsh or swamp hay, good quality	0.32	0.10	1.22	0.69	54	29	59	58	37 †
Millet hay, foxtail varieties	0.29	0.16	1.31	1.70	60	64	62	57	..
Millet hay, hog millet, or proso	..	..	1.49	..	..	..	..	..	..
Millet hay, Japanese	0.20	..	1.33	2.10	61	47	64	56	5
Millet hay, pearl, or cat-tail	..	..	1.07	..	63	46	67	59	2
Millet straw	0.08	..	0.61	1.44	..	..	..	..	..
Milo fodder	0.35	0.18	1.28	..	38	63	61	62	7
Milo stover	0.58	0.11	0.51	..	..	..	..	..	..
Mint hay	1.51	0.19	2.03	..	..	..	..	..	..
Mixed hay, good, less than 30% legumes	0.59	0.18	1.34	1.47	53	40	54	60	16
Mixed hay, good, less than 30% legumes, barn-dried	..	..	1.41	..	54	37	54	61	13
Mixed hay, good, more than 30% legumes	0.90	0.19	1.65	1.46	70	25	44	67	2
Mixed hay, excellent, mostly legumes	0.98	0.22	2.29	..	..	..	..	..	..
Mixed hay, cut very early	1.00	0.27	2.13	..	..	..	..	..	..
Napier grass hay	..	..	1.31	..	..	..	..	..	..
Natal grass hay	0.45	0.29	1.18	..	..	69	59	52	4
Native hay, western mt. states, good quality	0.53	0.16	1.36	..	60	39	62	62	22
Native hay, western mt. states, mature and weathered	0.53	0.07	0.62	..	40	25	46	43	19
Needle grass hay (*Stipa,* spp.)	..	..	1.15	..	..	..	..	..	..
Oak leaves, live oak, dried	..	..	1.49	..	0	30	10	27	1
Oat chaff	0.80	0.30	0.94	0.86	16	42	39	43	2 †
Oat hay	0.21	0.19	1.31	0.83	60	65	51	57	46
Oat hay, wild (*Avena fatua*)	0.22	0.25	1.06	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Oat hulls	92.8	1.5	31.7	20.1	4.6	1.4	29.2	51.3	6.3	40
Oat huller feed *	92.9	0.5	30.7	60.4	2.9	1.0	32.6	50.5	5.9	2
Oat straw	89.8	0.7	44.8	63.0	4.1	2.2	36.3	40.9	6.3	76
Oat straw pulp, treated with sodium hydroxide, wet	28.7	0	20.6	..	0.5	0.4	17.8	8.6	1.4	..
Oat-grass hay, tall	88.7	3.5	47.4	12.5	7.5	2.4	30.1	42.7	6.0	15
Orchard grass hay, good	88.7	4.2	49.7	10.8	8.1	2.9	30.4	40.5	6.8	55
Orchard grass hay, cut very early	89.9	8.8	63.5	6.2	13.9	3.7	26.6	38.1	7.6	2
Panic grass hay (*Panicum*, spp.) *	92.1	4.2	47.1	10.2	8.3	2.3	29.5	44.9	7.1	21
Para grass hay	90.2	1.9	41.6	20.9	4.6	0.9	33.6	44.5	6.6	3
Pasture grasses and clovers, mixed, from closely-grazed, fertile pasture, dried (northern states)	90.0	15.0	66.7	3.4	20.3	3.6	19.7	38.7	7.7	708
Pasture grasses, mixed, from poor to fair pasture, before heading, dried *	90.0	9.6	53.9	4.6	14.1	2.3	19.4	43.2	11.0	40
Pasture grass, western plains, growing, dried *	90.0	7.9	56.5	6.2	11.6	2.5	28.0	40.2	7.7	165
Pasture grass, western plains, mature, dried *	90.0	0.9	43.5	47.3	4.6	2.3	31.9	45.3	5.9	165
Pasture grass, western plains, mature and weathered	90.0	0.2	41.3	205.5	3.3	1.8	34.1	44.5	6.3	330
Pasture grass and other forage on western mt. ranges, spring, dried *	90.0	12.6	67.4	4.3	17.0	3.1	14.0	49.1	6.8	96
Pasture grass and other forage on western mt. ranges, autumn, dried *	90.0	6.5	67.6	9.4	8.8	4.3	17.4	51.4	8.1	96
Pea hay, field	89.3	10.6	55.1	4.2	14.9	3.3	24.3	39.1	7.7	35
Pea straw, field	90.2	3.2	42.2	12.2	6.1	1.6	33.1	44.0	5.4	23
Pea-and-oat hay	89.1	8.6	52.9	5.2	12.1	2.9	27.2	39.1	7.8	32
Peanut hay, without nuts, good	90.6	5.4	47.3	7.8	10.0	3.2	23.6	44.2	9.6	91
Peanut hay, without nuts, stemmy *	90.0	4.7	39.7	7.4	10.0	3.2	34.2	34.0	8.6	..
Peanut hay, with nuts	92.0	10.2	71.6	6.0	13.4	12.6	23.0	34.9	8.1	11
Peanut hay, mowed	91.4	6.9	58.4	7.5	10.6	5.1	23.8	42.2	9.7	6
Peanut hulls	92.3	1.6	18.8	10.8	6.7	1.2	60.4	19.6	4.4	79
Peavine hay, from pea-cannery vines, sun-cured	86.3	8.6	54.2	5.3	11.9	2.4	23.0	42.2	6.8	8
Prairie hay, western, early-cut	91.0	3.7	45.7	11.4	7.4	2.6	29.2	43.1	8.7	45

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Oat hulls	0.20	0.10	0.74	0.48	32	64	37	34	50 †
Oat huller feed	..	..	0.46	..	..	..	..	..	..
Oat straw	0.24	0.09	0.66	2.00	18	36	59	51	38 †
Oat straw pulp, treated with sodium hydroxide, wet	..	..	0.08	..	0	22	86	59	11 †
Oat-grass hay, tall	..	0.14	1.20	1.36	46	48	58	56	15 †
Orchard grass hay, good	0.27	0.18	1.30	1.92	52	42	62	59	20
Orchard grass hay, cut very early	0.33	0.38	2.22	3.36	63	46	77	80	3
Panic grass hay (*Panicum,* spp.)	..	..	1.33	..	..	..	..	..	..
Para grass hay	0.35	0.35	0.74	1.44	..	45	53	47	3
Pasture grasses and clovers, mixed, from closely-grazed, fertile pasture, dried (northern states)	0.58	0.32	3.25	2.18	74	64	79	80	31
Pasture grasses, mixed, from poor to fair pasture, before heading, dried	0.41	0.12	2.26	0.74	..	..	..	..	..
Pasture grass, western plains, growing, dried	0.37	0.24	1.86	..	..	..	..	..	..
Pasture grass, western plains, mature, dried	0.34	0.14	0.74	..	..	..	..	..	..
Pasture grass, western plains, mature and weathered	0.33	0.09	0.53	..	7	38	56	46	24
Pasture grass and other forage on western mt. ranges, spring, dried	1.21	0.38	2.72	..	..	..	..	..	..
Pasture grass and other forage on western mt. ranges, autumn, dried	..	..	1.41	..	..	..	..	..	..
Pea hay, field	1.22	0.25	2.38	1.25	71	48	51	73	5 †
Pea straw, field	..	0.10	0.98	1.08	52	45	44	52	14 †
Pea-and-oat hay	0.72	0.22	1.94	1.04	71	58	60	62	10 †
Peanut hay, without nuts, good	1.12	0.13	1.60	1.25	54	57	46	61	13
Peanut hay, without nuts, stemmy	..	..	1.60	..	..	..	..	..	..
Peanut hay, with nuts	1.13	0.15	2.14	0.85	76	92	49	69	7
Peanut hay, mowed	..	..	1.70	..	65	60	51	77	8
Peanut hulls	0.25	0.06	1.07	0.82	24	13	24	12	4
Peavine hay, from pea-cannery vines, sun-cured	1.48	0.16	1.90	..	72	63	48	74	6
Prairie hay, western, early-cut	0.31	0.19	1.18	0.98	50	33	59	53	54

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Prairie hay, western, cut in midseason	**91.3**	**2.0**	**45.1**	21.6	6.0	3.0	29.7	44.0	8.6	42
Prairie hay, western, mature	**91.9**	**0.9**	**43.7**	47.6	4.4	2.6	30.9	46.5	7.5	110
Prairie hay, western, mature and weathered	**91.9**	**0.1**	**40.1**	400.0	2.9	2.3	31.5	48.7	6.5	6
Quack grass hay *	**89.0**	**2.5**	**40.3**	15.1	6.9	1.9	34.5	38.8	6.9	4
Quack grass hay, cut very early	**85.0**	**9.0**	**55.2**	5.1	12.8	2.9	25.6	38.1	5.6	1
Ramie meal *	**92.1**	**14.0**	**52.1**	2.7	19.4	3.8	19.7	35.8	13.4	10
Red top hay *	**91.2**	**3.3**	**49.3**	13.9	7.1	2.3	29.8	45.2	6.8	56
Reed canary grass hay	**91.1**	**4.9**	**45.1**	8.2	7.7	2.3	29.2	44.3	7.6	13
Rescue grass hay *	**90.2**	**5.0**	**50.8**	9.2	9.8	3.2	24.6	44.5	8.1	3
Rhodes grass hay	**89.0**	**2.6**	**51.4**	18.8	5.7	1.3	31.7	41.8	8.5	18
Rice hulls	**92.0**	**0.1**	**9.9**	98.0	3.0	0.8	40.7	28.4	19.1	40
Rice straw	**92.5**	**0.6**	**41.5**	68.2	3.9	1.4	33.5	39.2	14.5	[illegible]
Rush hay, western (*Juncus*, spp.)	**90.0**	**6.2**	**56.2**	8.1	9.4	1.8	29.2	44.2	5.4	49
Russian thistle hay	**87.5**	**5.8**	**37.9**	5.5	8.9	1.6	26.9	37.4	12.7	5
Rye grass hay, Italian	**88.6**	**3.4**	**52.3**	14.4	8.1	1.9	27.8	43.3	7.5	7
Rye grass hay, perennial	**88.0**	**4.7**	**52.5**	10.2	9.2	3.1	24.2	43.4	8.1	14
Rye grass hay, native western *	**87.4**	**3.3**	**52.2**	14.8	7.8	2.1	33.5	37.6	6.4	8
Rye hay *	**91.3**	**2.4**	**42.5**	16.7	6.7	2.1	36.5	41.0	5.0	15
Rye straw	**92.8**	**0**	**42.2**	..	3.5	1.2	38.7	45.9	3.5	8
Safflower hulls *	**91.3**	**0.2**	**14.8**	73.0	3.8	4.7	53.1	28.3	1.4	..
Salt bushes, dried	**93.5**	**10.2**	**36.6**	2.6	13.8	1.6	22.1	38.8	17.2	27
Salt-bush, winter range, dried	**90.0**	**3.0**	**41.5**	12.8	7.2	4.2	25.8	36.8	16.0	..
Salt grass hay, misc. var.*	**90.0**	**4.4**	**45.5**	9.3	8.1	1.8	28.8	39.5	11.8	6
Sanfoin hay (*Onobrychis viciaefolia*) *	**84.1**	**7.5**	**49.0**	5.5	10.5	2.6	19.7	44.2	7.1	5
Seaweed, dried (*Fucus*, spp.)	**88.7**	**2.0**	**41.0**	19.5	5.2	4.2	9.4	53.6	16.3	1
Seaweed, dried (*Laminaria*, spp.) *	**83.7**	**4.3**	**33.6**	6.8	11.4	1.1	8.6	45.8	16.8	1
Sedge hay, eastern (*Carex*, spp.) *	**90.7**	**3.3**	**48.5**	13.7	6.1	1.7	29.2	46.3	7.4	3
Sedge hay, western (*Carex*, spp.) *	**90.6**	**6.7**	**56.0**	7.4	10.1	2.4	27.3	44.0	6.8	76
Seradella hay	**89.0**	**11.5**	**47.5**	3.1	16.4	3.2	29.8	32.0	7.6	..
Sorghum bagasse, dried	**89.3**	**0.4**	**41.0**	101.5	3.1	1.4	31.3	50.0	3.5	3
Sorghum fodder, sweet, dry	**88.9**	**3.3**	**52.4**	14.9	6.2	2.4	25.1	48.1	7.1	65
Sorghum fodder, sweet, high in water	**65.7**	**2.4**	**39.7**	15.5	4.5	2.4	16.6	37.6	4.6	19
Sorghum, heads and forage, dehydrated *	**90.3**	**3.1**	**59.8**	18.3	5.6	1.7	18.5	56.7	7.8	9
Soybean hay, good, all analyses	**88.1**	**9.8**	**48.6**	4.0	14.6	2.9	28.1	35.7	6.8	114

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Prairie hay, western, cut in midseason	0.33	0.12	0.96	..	34	33	59	53	75
Prairie hay, western, mature	0.36	0.08	0.70	0.73	20	36	58	49	58
Prairie hay, western, mature and weathered	0.41	0.03	0.46	..	3	24	52	46	35
Quack grass hay	..	..	1.10	..	..	..	..	..	..
Quack grass hay, cut very early	..	..	2.05	..	70	35	75	65	3
Ramie meal	4.52	0.26	3.10	..	..	..	..	..	..
Redtop hay	0.39	0.20	1.14	1.72	..	..	..	..	..
Reed canary grass hay	0.33	0.16	1.23	..	63	13	55	53	1 †
Rescue grass hay	..	..	1.57		..	..	..	..	..
Rhodes grass hay	0.35	0.27	0.91	1.18	45	49	69	61	4
Rice hulls	0.08	0.08	0.48	0.31	4	47	6	23	4
Rice straw	0.19	0.07	0.62	1.22	16	40	62	48	27 †
Rush hay, western (*Juncus*, spp.)	..	..	1.50	..	66	56	68	63	4
Russian thistle hay	..	..	1.42	..	65	65	37	53	14
Rye grass hay, Italian	..	0.24	1.30	1.00	42	42	65	67	15 †
Rye grass hay, perennial	..	0.24	1.47	1.25	51	46	66	66	14 †
Rye grass hay, native western	..	..	1.25	..	..	..	..	..	..
Rye hay	..	0.18	1.07	1.05	..	..	..	..	..
Rye straw	0.26	0.09	0.56	0.90	0	44	55	43	12 †
Safflower hulls	..	..	0.61	..	..	..	..	..	..
Salt bushes, dried	1.88	0.11	2.21	4.69	74	41	16	55	5
Salt-bush, winter range, dried	2.13	0.09	1.15	..	42	66	45	56	20
Salt grass hay, misc. var.	..	..	1.30	..	..	..	..	..	..
Sanfoin hay (*Onobrychis viciaefolia*)	..	..	1.68	..	..	..	..	..	..
Seaweed, dried (*Fucus*, spp.)	..	..	.83	..	38	73	0	60	4 †
Seaweed, dried (*Laminaria*, spp.)	..	..	1.82	..	..	..	..	..	..
Sedge hay, eastern (*Carex*, spp.)	..	..	.98	..	..	..	..	..	..
Sedge hay, western (*Carex*, spp.)	0.60	0.24	1.62	..	..	..	..	..	..
Seradella hay	..	0.33	2.62	1.25	70	64	43	58	4 †
Sorghum bagasse, dried	..	..	.50	..	..	46	53	45	3
Sorghum fodder, sweet, dry	0.34	0.14	.99	1.29	54	64	61	63	22
Sorghum fodder, sweet, high in water	0.25	0.10	.72	0.96	..	..	..	..	..
Sorghum, heads and forage, dehydrated	0.39	0.16	.90	..	..	..	..	..	..
Soybean hay, good, all analyses	1.10	0.22	2.34	1.09	67	45	45	65	72

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Soybean hay, in bloom or before	88.0	12.0	52.4	3.4	16.7	3.3	20.6	37.8	9.6	8
Soybean hay, seed developing *	88.0	9.8	48.2	3.9	14.6	2.4	27.2	35.5	7.3	24
Soybean hay, seed well developed	88.0	10.8	52.5	3.9	15.2	4.7	26.7	35.2	6.2	19
Soybean hay, seed nearly ripe *	88.0	10.8	54.9	4.1	15.2	6.6	24.0	38.2	4.0	2
Soybean hay, poor quality, weathered	89.0	4.3	38.6	8.0	9.2	1.2	41.0	30.4	7.2	5
Soybean straw	88.9	1.1	38.6	34.1	3.9	1.2	41.2	37.5	5.1	17
Soybean and Sudan grass hay, chiefly Sudan *	89.0	3.6	50.8	13.1	7.4	2.2	31.1	43.4	4.9	1
Spanish moss, dried	89.2	0	51.4	..	5.0	2.4	26.6	47.7	7.[illegible]	3
Sudan grass hay, all analyses	89.4	4.3	48.6	10.3	8.8	1.6	28.0	42.9	8.1	[illegible]7
Sudan grass hay, before bloom *	89.6	6.3	50.0	6.9	11.2	1.5	26.1	41.3	9.5	33
Sudan grass hay, in bloom	89.2	4.7	51.8	10.0	8.4	1.5	30.7	41.8	6.8	2
Sudan grass hay, in seed	89.5	2.5	50.2	19.1	6.8	1.6	29.9	44.4	6.8	11
Sudan grass, young, dehydr.	88.0	9.3	59.0	5.3	14.5	2.5	20.4	41.2	9.4	45
Sudan grass straw	90.4	3.3	44.5	12.5	7.1	1.5	33.0	42.3	6.5	3
Sugar cane fodder, Japanese, dried *	89.0	0.7	55.3	78.0	1.3	1.8	19.7	64.3	1.9	1
Sugar cane bagasse, dried	91.8	0	20.5	..	1.2	0.4	46.7	41.0	2.5	2
Sugar cane pulp, dried	93.8	0	44.5	..	1.7	0.6	45.6	42.2	3.7	11
Sweet potato vines, dr. *	90.7	8.9	51.7	4.8	12.6	3.3	19.1	45.5	10.2	9
Teosinte fodder, dry *	89.4	4.9	50.0	9.2	9.1	1.9	26.4	41.7	10.3	4
Timothy hay, all analyses	89.0	3.0	49.1	15.4	6.6	2.3	30.3	44.8	5.0	391
Timothy hay, before bloom	89.0	6.1	56.6	8.3	9.7	2.7	27.9	42.2	6.5	17
Timothy hay, early bloom	89.0	4.2	51.7	11.3	7.6	2.3	30.1	44.3	4.7	38
Timothy hay, early bloom, barn-dried	89.0	4.6	50.9	10.1	8.0	2.1	29.0	45.2	4.7	2
Timothy hay, full bloom	89.0	3.2	51.1	15.0	6.4	2.5	30.4	44.8	4.9	53
Timothy hay, in bloom, nitrogen fertilized *	89.0	4.8	52.1	9.9	8.8	2.1	31.6	42.6	3.9	17
Timothy hay, late bloom to early seed	89.0	2.8	47.9	16.1	6.1	2.7	29.9	45.4	4.9	43
Timothy hay, late seed	89.0	1.9	41.9	21.1	5.3	2.3	31.2	45.7	4.5	36
Timothy hay, in bloom, dehydrated	89.0	3.9	54.1	12.9	7.7	2.3	28.3	45.5	5.2	13
Timothy hay, second cutting *	88.7	9.5	56.1	4.9	15.0	4.6	25.4	36.5	7.2	3
Timothy and clover hay, one-fourth clover *	88.8	4.0	49.8	11.5	7.9	2.4	29.5	43.7	5.3	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Soybean hay, in bloom or before	1.29	0.34	2.67	..	72	38	54	70	4 †
Soybean hay, seed developing	1.24	0.25	2.34	0.90	..	..	..	..	..
Soybean hay, seed well developed	1.14	0.27	2.43	0.71	71	36	47	72	5
Soybean hay, seed nearly ripe	0.96	0.31	2.43	0.81	..	..	..	..	..
Soybean hay, poor quality, weathered	..	..	1.47	..	47	32	40	56	9
Soybean straw	..	0.05	.62	0.53	29	31	36	58	18
Soybean and Sudan grass cut chiefly Sudan	..	..	1.18	..	..	..	..	..	..
Sphagnum moss, dried	..	0.04	.80	0.46	0	16	52	77	2
Sudan grass hay, all analyses	0.36	0.27	1.41	1.88	49	52	64	57	16
Sudan grass hay, before bloom	0.41	0.28	1.79	..	..	..	..	..	..
Sudan grass hay, in bloom	..	..	1.34	..	56	60	65	60	4
Sudan grass hay, in seed	..	..	1.09	..	37	52	64	60	5
Sudan grass, young, dehydr.	0.52	0.39	2.32	..	64	66	72	76	10
Sudan grass straw	..	..	1.14	..	46	34	60	48	2
Sugar cane fodder, Japanese, dried	0.32	0.14	.21	0.58	..	..	..	..	..
Sugar cane bagasse, dried	..	..	.19	..	0	0	29	17	12
Sugar cane pulp, dried	..	..	.27	..	0	54	58	41	5
Sweet potato vines, dried	..	..	2.02	..	..	..	..	..	..
Teosinte fodder, dry	..	0.17	1.46	0.88	..	..	..	..	..
Timothy hay, all analyses	0.35	0.14	1.06	1.59	46	46	57	59	273
Timothy hay, before bloom	..	..	1.55	..	63	40	74	65	26
Timothy hay, early bloom	0.41	0.21	1.22	..	55	42	61	61	13
Timothy hay, early bloom, barn-dried	0.55	0.21	1.28	..	58	31	58	62	4
Timothy hay, full bloom	..	0.20	1.02	1.50	50	44	61	60	19 †
Timothy hay, in bloom, nitrogen fertilized	0.40	0.21	1.41	1.41	..	..	..	..	..
Timothy hay, late bloom to early seed	..	..	0.98	..	46	50	51	59	21
Timothy hay, late seed	0.14	0.15	0.85	1.41	36	36	49	50	15
Timothy hay, in bloom, dehydrated	..	..	1.23	..	50	54	60	67	14
Timothy hay, second cutting	0.58	0.19	2.40	..	..	..	..	..	..
Timothy and clover hay, one-fourth clover	0.58	0.15	1.26	1.60	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. pro- tein	Total dig. nutri- ents	Nutri- tive ratio	Average total composition					
					Pro- tein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Trefoil hay, big *	89.3	8.3	53.7	5.5	12.0	2.7	21.9	45.4	7.3	1
Velvet bean hay	92.8	9.5	56.2	4.9	16.4	3.1	27.5	38.4	7.4	4
Vetch hay, common ..	89.0	10.1	55.3	4.5	13.3	1.1	25.2	43.2	6.2	40
Vetch hay, hairy	88.0	15.2	57.1	2.8	19.3	2.6	24.5	33.1	8.5	17
Vetch-and-oat hay, over half vetch	87.6	8.4	50.7	5.0	11.9	2.7	27.3	37.5	8.2	13
Vetch-and-wheat hay, cut early	90.0	11.4	58.0	4.1	15.4	2.2	28.8	36.4	7.2	4
Wheat chaff	90.0	2.0	35.8	16.9	4.4	1.5	29.4	47.1	7.6	1
Wheat hay	90.4	3.3	46.7	13.2	6.1	1.8	26.1	50.0	6.4	26
Wheat straw	92.6	0.3	40.6	134.3	3.9	1.5	37.0	41.9	8.3	79
Wheatgrass hay, crested, cut early	90.0	6.5	50.8	6.8	9.2	2.0	32.2	40.2	6.4	15
Wheatgrass hay, intermediate *	90.0	4.0	48.7	11.2	6.9	2.0	31.7	38.7	10.7	1
Wheatgrass hay, slender	90.0	4.6	50.8	10.0	8.0	2.1	32.2	41.0	6.7	8
Wheatgrass hay, western, cut early *	88.0	6.0	48.9	7.2	8.5	2.6	29.2	40.1	7.6	19
Wheatgrass hay, western, mature *	88.0	1.1	45.2	40.1	3.5	2.7	32.3	41.4	8.1	16
Winter fat, or white sage, dried (*Eurotia lanata*) *	92.6	6.5	45.7	6.0	12.9	1.9	27.4	40.8	9.6	8
Wiregrass hay, southern (*Aristida,* spp.) *	90.0	1.1	44.1	39.1	5.5	1.4	31.8	47.9	3.4	50
Wiregrass hay, western (*Aristida,* spp.) * ..	90.0	1.7	42.6	24.1	6.4	1.3	34.1	41.0	7.2	6
Yucca, or beargrass, dr. *	92.6	2.4	51.2	20.3	6.6	2.2	38.6	38.3	6.9	4
Green Roughages, Roots, etc.										
Alfalfa, green, all analyses	24.4	3.5	14.8	3.2	4.6	0.9	6.7	10.0	2.2	243
Alfalfa, very young ...	18.0	3.9	12.9	2.3	4.7	0.8	3.1	7.6	1.8	11
Alfalfa, before bloom .	19.9	3.3	12.3	2.7	4.4	0.7	4.7	8.2	1.9	39
Alfalfa, early bloom ..	22.5	3.6	14.3	3.0	4.6	0.7	5.8	9.3	2.1	15
Alfalfa, ½ to full bloom	25.3	3.4	14.9	3.4	4.6	0.9	7.2	10.5	2.1	17
Alfalfa, past bloom ..	29.3	2.7	14.6	4.4	3.6	0.7	11.9	10.9	2.2	8
Alfalfa and bromegrass pasture, half alfalfa	22.5	3.3	13.9	3.2	4.8	0.8	5.3	9.4	2.2	..
Alfalfa and timothy pasture, half alfalfa * ..	21.9	3.5	14.4	3.1	4.6	0.8	4.7	9.6	2.2	..
Alfilaria (*Erodium cicutarium*) *	16.4	2.1	9.1	3.3	2.8	0.4	3.2	6.8	3.2	3
Apples *	17.9	0.2	13.3	65.5	0.5	0.4	1.3	15.3	0.4	10
Artichoke tops *	27.2	0.8	18.1	21.6	1.4	0.3	4.9	18.5	2.1	1
Artichoke tubers *	20.5	1.2	15.9	12.3	2.0	0.1	0.8	15.9	1.7	22
Bahia grass *	30.0	1.1	15.9	13.5	2.4	0.5	9.4	14.1	3.6	2
Barley fodder	22.2	2.3	14.2	5.2	3.2	0.7	5.6	10.7	2.0	19
Barley pasture *	20.0	3.9	12.5	2.2	5.2	0.8	3.7	7.0	3.3	21
Beet tops, sugar	17.8	1.7	10.4	5.1	2.7	0.2	2.0	9.0	3.9	86

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Dry Roughages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Trefoil hay, big	..	..	1.92	..	..	..	..	..	..
Velvet bean hay	..	0.24	2.62	2.20	58	66	68	61	4 †
Vetch hay, common	1.18	0.32	2.13	2.22	76	49	51	72	28 †
Vetch hay, hairy	1.13	0.32	3.09	1.96	79	67	59	71	8 †
Vetch-and-oat hay, over half vetch	0.76	0.27	1.90	1.51	71	52	51	67	23 †
Vetch-and-wheat hay, cut early	..	..	2.46	..	74	64	65	68	4 †
Wheat chaff	0.21	0.14	0.70	0.50	46	100	33	44	4 †
Wheat hay	0.14	0.18	0.98	1.47	54	42	41	62	24
Wheat straw	0.15	0.07	0.62	1.18	8	41	52	47	54 †
Wheatgrass hay, crested, cut early	..	..	1.47	..	71	43	64	54	5
Wheatgrass hay, intermediate	0.32	..	1.10	..	..	..	..	..	..
Wheatgrass hay, slender	0.30	0.24	1.28	2.41	58	31	61	62	15
Wheatgrass hay, western, cut early	0.34	0.22	1.36	..	..	..	..	..	..
Wheatgrass hay, western, mature	0.15	0.07	0.56	..	..	..	..	..	..
Winterfat, or white sage, dried (*Eurotia lanata*)	..	..	2.06	..	..	..	..	..	..
Wiregrass hay, southern (*Aristida*, spp.)	0.15	0.14	0.88	..	..	..	..	..	..
Wiregrass hay, western (*Aristida*, spp.)	..	..	1.02	..	..	..	..	..	..
Yucca, or beargrass, dried	..	..	1.06	..	..	..	..	..	..
Green Roughages, Roots, etc.									
Alfalfa, green, all analyses	0.40	0.06	0.74	0.53	76	36	48	74	110
Alfalfa, very young	..	..	0.75	..	82	49	57	84	17
Alfalfa, before bloom	0.45	0.07	0.70	0.47	76	27	51	75	32
Alfalfa, early bloom	0.53	0.07	0.74	0.43	79	31	50	78	7
Alfalfa, ½ to full bloom	0.51	0.07	0.74	0.55	73	36	46	71	11
Alfalfa, past bloom	0.36	0.06	0.58	0.56	75	54	38	60	4
Alfalfa and bromegrass pasture, half alfalfa	0.28	0.07	0.77	0.63	69	44	67	66	4
Alfalfa and timothy pasture, half alfalfa	0.30	0.08	0.74	0.49	..	..	..	..	..
Alfilaria (*Erodium cicutarium*)	0.28	0.06	0.45	..	..	..	..	..	..
Apples	0.01	0.01	0.08	0.14	..	..	..	..	..
Artichoke tops	0.44	0.03	0.22	0.37	..	..	..	..	..
Artichoke tubers	..	0.06	0.32	0.41	..	..	..	..	..
Bahia grass	0.13	0.04	0.38	..	..	..	..	..	..
Barley fodder	0.07	0.08	0.51	0.35	71	56	59	72	6
Barley pasture	0.12	0.08	0.83	..	..	..	..	..	..
Beet tops, sugar	0.18	0.04	0.43	1.03	64	35	67	80	26

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Beets (roots), common *	13.0	1.2	10.5	7.8	1.6	0.1	0.9	8.9	1.5	23
Beets (roots), sugar ..	16.4	1.2	13.7	10.4	1.6	0.1	1.0	12.6	1.1	86
Beggarweed *	27.1	2.8	14.3	4.1	4.2	0.5	7.5	11.7	3.2	3
Bent grass, Colonial, pasture *	29.4	4.2	19.7	3.7	5.7	1.1	6.4	13.2	3.0	37
Bermuda grass, in bloom*	35.0	1.9	20.5	9.8	3.6	0.7	9.8	17.4	3.5	3
Bermuda grass pasture *	25.0	2.0	15.0	6.5	2.8	0.5	6.4	12.2	3.1	25
Bermuda grass, Coastal, pasture fertilized with nitrogen	25.0	3.0	16.5	4.5	4.1	0.7	6.7	12.3	1.2	5
Berseem, or Egyptian clover	18.8	2.1	12.1	4.8	2.7	0.7	4.4	8.2	2.8	15
Birdsfoot trefoil pasture *	20.0	4.6	15.0	2.3	5.6	1.0	2.6	9.3	1.5	[illegible]
Birdsfoot trefoil *	25.0	2.7	15.2	4.6	3.7	1.1	7.1	11.7	1.4	1
Bluegrass, Canada * ..	33.2	1.9	19.9	9.5	3.0	1.2	10.3	16.1	2.6	[illegible]
Bluegrass, Kentucky, pasture	30.2	4.1	20.7	4.0	5.5	1.2	7.6	13.4	2.5	174
Bluegrass, Kentucky, heading out	33.0	4.4	22.9	4.2	6.1	1.3	8.9	14.6	2.1	5
Bluegrass, Kentucky, headed out	36.4	3.0	21.9	6.3	4.8	1.4	10.6	16.8	2.8	10
Bluegrass, Kentucky, in seed	42.2	1.7	21.2	11.5	4.0	1.3	14.7	19.4	2.8	8
Bluegrass, Kentucky, and white clover pasture *	24.0	3.8	16.6	3.4	4.9	0.8	4.4	11.2	2.7	11
Bluejoint (*Calamagrostis Canadensis*) *	44.6	2.7	25.1	8.3	4.1	1.2	15.2	20.0	4.1	3
Bluestem pasture, very young (*Andropogon,* spp.) *	22.0	2.1	14.9	6.1	3.2	0.7	4.6	11.7	1.8	5
Bluestem pasture, active growth	34.1	1.3	19.5	14.0	2.9	0.8	10.7	16.7	3.0	70
Bluestem, mature * ...	50.8	1.1	27.0	23.5	3.6	1.4	17.5	26.3	2.0	1
Bluestem, mature and weathered	84.7	0	37.3	..	2.7	1.6	29.7	43.6	7.1	36
Bromegrass, smooth, young pasture	25.0	3.9	18.3	3.7	5.1	1.0	5.8	10.7	2.4	19
Bromegrass, smooth, heading out	30.0	2.8	20.3	6.3	4.2	1.3	9.0	13.4	2.1	8
Bromegrass, smooth, mature	53.0	1.2	27.9	22.3	2.8	1.2	19.3	26.1	3.6	4
Bromegrass, smooth, mature and weathered *	85.0	0.7	39.8	55.9	3.4	1.1	32.4	43.1	5.0	6
Bromegrasses, wild (*Bromus,* spp.) * ..	36.1	2.9	23.5	7.1	4.4	1.0	11.6	15.6	3.5	20
Buckwheat fodder	36.6	2.9	21.7	6.5	4.6	0.9	8.0	19.5	3.6	1
Buffalo grass (*Buchloe dactyloides*)	36.7	1.9	20.5	9.8	3.5	0.7	9.8	18.1	4.6	24
Cabbage, entire	9.4	1.9	8.1	3.3	2.2	0.3	1.0	5.0	0.9	6

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Beets (roots), common	0.03	0.04	0.26	0.28	..	..	..	..	..
Beets (roots), sugar ..	0.04	0.04	0.26	0.25	72	0	34	97	30
Beggarweed	..	0.12	0.67	0.47	..	..	..	..	..
Bent grass, Colonial, pasture	0.19	0.12	0.91	0.65	..	..	..	..	..
Bermuda grass, in bloom	0.14	0.07	0.58	0.55	..	..	..	..	..
Bermuda grass pasture .	0.14	0.05	0.45	0.55	..	..	..	..	..
Bermuda grass, Coastal, pasture fertilized with nitrogen	..	..	0.66	..	73	63	67	65	..
Berseem, or Egyptian clover	0.67	0.06	0.43	0.42	77	59	60	79	97
Birdsfoot trefoil pasture	..	..	0.90	..	..	..	..	..	..
Birdsfoot trefoil	0.44	0.05	0.59	0.46	..	..	..	..	..
Bluegrass, Canada	0.14	0.11	0.48	0.53	..	..	..	..	..
Bluegrass, Kentucky, pasture	0.16	0.13	0.88	0.59	74	60	72	71	52
Bluegrass, Kentucky, heading out	..	..	0.98	..	72	57	71	72	28
Bluegrass, Kentucky, headed out	0.09	0.10	0.77	0.73	62	57	59	65	13
Bluegrass, Kentucky, in seed	0.08	0.13	0.64	0.87	42	58	46	57	6
Bluegrass, Ky., and white clover pasture	0.31	0.11	0.78	..	..	..	..	..	..
Bluejoint (*Calamagrostis Canadensis*)	..	0.10	0.66	..	..	..	..	..	..
Bluestem pasture, very young (*Andropogon,* spp.)	..	..	0.51	..	..	..	..	..	..
Bluestem pasture, active growth	0.14	0.05	0.46	0.46	45	34	68	62	10
Bluestem, mature	0.20	0.07	0.58	..	..	..	..	..	..
Bluestem, mature and weathered	0.36	0.05	0.43	..	0	3	62	43	8
Bromegrass, smooth, young pasture	0.12	0.08	0.82	0.79	77	58	80	79	32
Bromegrass, smooth, heading out	..	..	0.67	..	67	52	72	71	33
Bromegrass, smooth, mature	0.14	0.09	0.45	..	42	44	54	58	3
Bromegrass, smooth, mature and weathered	..	0.03	0.54	..	..	..	..	..	..
Bromegrasses, wild (*Bromus,* spp.)	..	0.10	0.70	0.79	..	..	..	..	..
Buckwheat fodder	..	..	0.74	..	64	50	58	67	..
Buffalo grass (*Buchloe dactyloides*)	0.23	0.06	0.56	..	54	62	65	62	1
Cabbage, entire	0.06	0.03	0.35	0.24	86	70	91	96	2

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green Roughages Roots, etc.—Cont.										
Cabbage, head, without outer leaves . . .	**7.6**	**1.1**	**6.6**	5.0	1.4	0.2	0.9	4.4	0.7	. .
Cabbage waste, outer leaves	**15.8**	**1.8**	**10.6**	4.9	2.6	0.4	2.7	7.1	3.0	3
Cactus, cane, entire plant *	**21.0**	**0.7**	**12.3**	16.6	1.5	0.4	3.3	12.4	3.4	. .
Cactus, cane, fruit * . .	**18.6**	**0.7**	**11.3**	15.1	1.5	0.8	3.2	10.4	2.7	35
Cactus, cane, stems * .	**21.7**	**0.7**	**12.5**	16.9	1.5	0.4	3.4	12.6	3.8	42
Cactus, prickly pear, all anal.	**16.6**	**0.4**	**9.4**	22.5	0.8	0.3	2.3	9.8	3.4	99
Cactus, prickly pear, young joints *	**12.9**	**0.4**	**7.6**	18.0	0.9	0.4	1.2	7.8	[illegible]	[illegible]
Carpet grass pasture . .	**25.0**	**1.2**	**16.0**	12.3	2.3	0.4	6.6	12.5	[illegible]	15
Carrots, roots	**11.9**	**0.9**	**10.3**	10.4	1.2	0.2	1.1	8.2	[illegible]	[illegible]
Carrot tops *	**16.0**	**1.7**	**12.4**	6.3	2.1	0.6	2.9	8.0	[illegible]	1[illegible]
Cassava roots	**32.6**	**0**	**25.7**	. .	1.1	0.3	1.4	28.8	1.[illegible]	8
Chufa tubers *	**26.5**	**0.8**	**18.1**	21.6	2.1	1.8	2.0	18.8	1.8	1
Clover, alsike, pasture *	**22.0**	**3.2**	**15.7**	3.9	4.1	0.9	4.7	10.4	1.9	5
Clover, alsike, in bloom *	**23.6**	**2.7**	**15.9**	4.9	3.7	0.7	6.4	10.5	2.3	22
Clover, bur *	**20.8**	**3.9**	**15.1**	2.9	5.1	1.7	3.9	7.8	2.3	3
Clover, crimson	**17.4**	**2.3**	**11.3**	3.9	3.0	0.6	4.7	7.4	1.7	22
Clover, crimson, and rye grass pasture * . .	**18.3**	**3.0**	**13.2**	3.4	3.9	1.1	3.4	8.0	1.9	30
Clover, hop	**25.6**	**2.8**	**18.5**	5.6	4.5	1.0	5.0	13.4	1.7	11
Clover, Ladino, pasture	**16.6**	**3.3**	**12.4**	2.8	4.1	0.8	2.5	7.5	1.7	42
Clover, Ladino, and grass pasture, much Ladino*	**20.0**	**2.6**	**12.9**	4.0	3.5	0.5	4.5	9.1	2.4	36
Clover, Ladino, and grass pasture, mostly grass *	**20.0**	**2.0**	**13.2**	5.6	2.7	0.6	5.0	9.6	2.1	54
Clover, Ladino, and tall fescue *	**25.4**	**3.8**	**17.1**	3.5	5.0	1.4	5.3	11.1	2.6	118
Clover, mammoth red *	**25.1**	**2.8**	**16.4**	4.9	4.0	0.5	7.3	11.0	2.3	7
Clover, red, all analyses	**24.5**	**2.8**	**16.6**	4.9	4.0	0.9	6.5	11.0	2.1	137
Clover, red, pasture . .	**18.1**	**2.8**	**13.2**	3.7	3.7	0.9	2.9	9.0	1.6	6
Clover, red, in bloom .	**27.3**	**3.0**	**19.0**	5.3	4.1	1.1	7.7	12.4	2.0	51
Clover, red, second crop *	**34.4**	**3.8**	**24.1**	5.3	5.3	1.3	9.1	16.2	2.5	7
Clover, sweet, before bloom	**20.8**	**3.2**	**12.8**	3.0	4.1	0.7	4.9	9.2	1.9	13
Clover, sweet, in bloom	**29.2**	**3.8**	**19.1**	4.0	4.9	0.8	9.5	11.8	2.2	11
Clover, white, pasture *	**17.8**	**4.1**	**12.9**	2.1	5.1	0.6	2.8	7.2	2.1	139
Clover and mixed grasses, hay stage . .	**27.3**	**1.9**	**18.9**	8.9	3.0	0.9	8.5	13.3	1.6	19
Clover and mixed grass pasture, well grazed	**20.0**	**3.4**	**13.9**	3.1	4.5	0.8	3.6	9.6	1.5	15
Corn ears, sweet, including husks *	**37.8**	**2.1**	**29.2**	12.9	3.8	2.6	4.3	26.2	0.9	3
Corn fodder, dent, all anal.	**24.0**	**1.2**	**16.3**	12.6	2.0	0.6	5.6	14.5	1.3	340
Corn fodder, dent, in tassel	**15.0**	**1.0**	**9.7**	8.7	1.6	0.3	4.2	7.8	1.1	19

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phos-phorus	Nitro-gen	Potas-sium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cabbage, head, without outer leaves	0.05	0.03	0.22	0.25	77	43	100	100	2
Cabbage waste, outer leaves	..	..	0.42	..	69	44	81	87	3
Cactus, cane, entire plant	..	0.01	0.24	0.17	..	..	..	..	..
Cactus, cane, fruit	..	..	0.24	..	..	..	..	..	..
Cactus, cane, stems	..	0.04	0.24	0.40	..	..	..	..	..
Cactus, prickly pear, all anal.	1.52	0.02	0.13	0.42	44	72	40	78	8 †
C[illegible]s, [illegible]ickly pear, B[illegible]ints	..	0.02	0.14	0.27	..	..	..	..	..
[illegible]s pasture	0.10	0.04	0.37	0.23	50	84	55	84	1 †
Bin[illegible]s	0.05	0.04	0.19	0.25	73	77	100	97	18 †
Birds[illegible]ps	0.31	0.03	0.34	0.30	..	..	..	..	..
[illegible] roots	..	0.04	0.18	0.33	2	52	57	85	7
[illegible] tubers	0.01	0.07	0.34	0.14	..	..	..	..	..
Clover, alsike, pasture	0.32	0.06	0.66	..	..	..	..	..	..
Clover, alsike, in bloom	0.30	0.06	0.59	0.61	..	..	..	..	..
Clover, bur	..	..	0.82	..	..	..	..	..	..
Clover, crimson	0.24	0.05	0.48	0.54	77	66	56	74	3
Clover, crimson, and rye grass pasture	0.12	0.12	0.62	..	..	..	..	..	..
Clover, hop	0.26	0.09	0.72	0.52	63	51	71	82	1
Clover, Ladino, pasture	0.21	0.07	0.66	0.31	81	60	67	84	45
Clover, Ladino, and grass pasture, much Ladino	0.30	0.08	0.56	..	..	..	..	..	..
Clover, Ladino, and grass pasture, mostly grass	0.16	0.07	0.43	..	..	..	..	..	..
Clover, Ladino, and tall fescue	0.19	0.09	0.80	..	..	..	..	..	..
Clover, mammoth red	..	..	0.64	..	..	..	..	..	..
Clover, red, all analyses	0.41	0.06	0.64	0.57	71	67	57	79	45
Clover, red, pasture	0.35	0.05	0.59	0.47	77	69	54	83	10
Clover, red, in bloom	0.48	0.09	0.66	0.54	72	75	58	79	2 †
Clover, red, second crop	0.48	0.09	0.85	0.79	..	..	..	..	..
Clover, sweet, before bloom	0.34	0.10	0.66	..	79	52	50	68	2
Clover, sweet, in bloom	0.36	0.07	0.78	0.42	77	50	66	69	2
Clover, white, pasture	0.25	0.09	0.82	0.38	..	..	..	..	..
Clover and mixed grasses, hay stage	0.16	0.08	0.48	..	62	60	66	77	4
Clover and mixed grass pasture, well grazed	0.23	0.07	0.72	0.71	75	52	74	72	90
Corn ears, sweet, including husks	..	..	0.61	..	..	..	..	..	..
Corn fodder, dent, all anal.	0.07	0.05	0.32	0.30	59	74	63	73	48
Corn fodder, dent, in tassel	..	..	0.26	..	61	69	64	71	15

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. pro-tein	Total dig. nutri-ents	Nutri-tive ratio	Average total composition					
					Pro-tein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn fodder, dent, in milk	19.9	0.9	13.7	14.2	1.6	0.5	5.1	11.6	1.1	29
Corn fodder, dent, dough to glazing . . .	26.9	1.2	19.1	14.9	2.1	0.7	6.2	16.6	1.3	62
Corn fodder, dent, kernels ripe	37.7	1.7	26.0	14.3	3.0	1.0	7.8	24.2	1.7	20
Corn fodder, dent, drouth-stricken corn *	26.4	1.5	17.8	10.9	2.6	0.4	6.8	15.0	1.6	18
Corn fodder, flint, all anal.*	22.3	1.2	15.2	11.7	2.0	0.6	4.9	13.6	1.2	139
Corn fodder, flint, in tassel *	11.6	0.9	7.4	7.2	1.5	0.3	3.3	5.5	1.0	13
Corn fodder, flint, in milk *	17.0	0.9	11.5	11.8	1.6	0.3	4.2	9.8	1.1	12
Corn fodder, flint, dough to glazing * .	24.7	1.3	17.7	12.6	2.2	0.8	5.1	15.3	1.3	33
Corn fodder, flint, kernels ripe *	41.2	2.0	28.5	13.3	3.5	1.3	8.1	26.2	2.1	10
Corn fodder, popcorn, young *	16.9	0.8	10.9	12.6	1.3	0.4	6.0	8.2	1.0	2
Corn fodder, sweet, be-fore milk *	10.0	0.6	6.4	9.7	1.0	0.3	2.5	5.2	1.0	5
Corn fodder, sweet, roasting ears or later	20.3	1.2	14.2	10.8	1.9	0.6	4.4	12.2	1.2	55
Corn leaves and tops *	15.9	1.2	10.4	7.7	1.9	0.6	4.4	7.8	1.2	2
Corn stover, green, field corn (ears removed)	22.7	0.5	13.0	25.0	1.3	0.4	6.0	13.6	1.4	18
Corn stover, sweet (ears removed) * . .	21.5	0.6	12.2	19.3	1.6	0.4	5.6	12.6	1.3	3
Cowpeas	16.3	2.2	10.8	3.9	3.0	0.5	3.8	7.0	2.0	147
Cowpeas and corn * . .	20.0	1.3	13.2	9.2	2.1	0.4	5.3	10.4	1.8	1
Crabgrass *	30.9	1.5	17.6	10.7	2.7	1.0	9.1	13.8	4.3	6
Crotalaria intermedia *	25.6	2.3	10.6	3.6	3.7	0.6	10.3	9.7	1.3	21
Dallis grass pasture * .	25.0	2.2	16.0	6.3	3.0	0.6	7.2	11.0	3.2	31
Dallis grass, in bloom *	30.0	1.3	17.4	12.4	2.1	0.7	9.7	14.6	2.9	1
Darso fodder *	29.0	0.7	19.5	26.9	1.3	0.6	7.3	17.7	2.1	. .
Desmanthus, or dwarf koa (*Desmanthus virgatus*)	44.2	3.2	24.0	6.5	5.2	0.9	19.6	16.0	2.5	1
Dropseed, alkali, young (*Sporobolus airoides*) *	35.0	2.5	22.8	8.1	3.7	0.7	11.9	15.4	3.3	6
Dropseed, alkali, in bloom *	40.0	1.3	21.8	15.8	2.5	0.7	14.5	18.6	3.7	4
Dropseed, mesa, in bloom (*Sporobolus flexuosus*)	35.0	2.4	22.1	8.2	3.1	0.6	13.5	15.6	2.2	1
Dropseed, mesa, nearly mature	50.0	1.8	27.1	14.1	3.6	0.6	18.7	24.6	2.5	1
Durra fodder *	22.4	1.1	14.8	12.5	2.0	0.6	6.2	11.8	1.8	3
Fescue, meadow *	30.5	1.6	18.5	10.6	3.0	1.0	10.1	14.0	2.4	33

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn fodder, dent, in milk	..	..	0.26	..	59	73	62	76	10
Corn fodder, dent, dough to glazing	0.08	0.07	0.34	0.38	59	79	62	77	5
Corn fodder, dent, kernels ripe	0.11	0.07	0.48	0.37	58	78	62	73	18
Corn fodder, dent, drouth-stricken corn	..	..	0.42	..	..	..	..	..	..
Corn fodder, flint, all anal.	..	0.04	0.32	0.33	..	..	..	..	..
Corn fodder, flint, in tassel	..	..	0.24	..	..	..	..	..	..
Corn fodder, flint, in milk	..	..	0.26	..	..	..	..	..	..
Corn fodder, flint, dough to glazing	..	..	0.35	..	..	..	..	..	..
Corn fodder, flint, kernels ripe	..	..	0.56	..	..	..	..	..	..
Corn fodder, popcorn, young	..	..	0.21	..	..	..	..	..	..
Corn fodder, sweet, before milk	..	0.02	0.16	0.16	..	..	..	..	..
Corn fodder, sweet, roasting ears or later	..	0.04	0.30	0.32	62	75	60	77	12
Corn leaves and tops	..	..	0.30	..	..	..	..	..	..
Corn stover, green, field corn (ears removed)	0.14	0.02	0.21	0.37	..	..	..	..	..
Corn stover, sweet (ears removed)	..	..	0.26	..	..	..	..	..	..
Cowpeas	0.25	0.05	0.48	0.27	74	60	58	82	31 †
Cowpeas and corn	..	..	0.34	..	..	..	..	..	..
Crabgrass	..	..	0.43	..	..	..	..	..	..
Crotalaria intermedia	0.18	0.06	0.59	0.76	..	..	..	..	..
Dallis grass pasture	0.14	0.05	0.48	0.43	..	..	..	..	..
Dallis grass, in bloom	0.14	0.04	0.34	..	..	..	..	..	..
Darso fodder	..	0.04	0.21	..	..	..	..	..	..
Desmanthus, or dwarf koa (*Desmanthus virgatus*)	..	..	0.83	..	61	57	43	70	4
Dropseed, alkali, young (*Sporobolus airoides*)	..	..	0.59	..	..	..	..	..	..
Dropseed, alkali, in bloom	..	..	0.40	..	..	..	..	..	..
Dropseed, mesa, in bloom (*Sporobolus flexuosus*)	0.12	0.06	0.50	..	76	68	68	62	4
Dropseed, mesa, nearly mature	0.10	0.09	0.58	..	49	40	63	53	4
Durra fodder	..	..	0.32	..	..	..	..	..	..
Fescue, meadow	0.17	0.12	0.48	0.82	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Fescue, sheep, pasture *	32.9	3.2	20.5	5.4	5.6	1.1	8.8	14.7	2.7	39
Fescue, tall, young pasture	25.0	3.2	17.8	4.6	4.4	1.3	5.9	11.3	2.1	8
Fescue, tall, older	30.0	2.2	18.3	7.3	3.7	1.6	7.7	14.3	2.7	9
Fescues, native (*Festuca*, spp.) *	36.0	1.9	21.8	10.5	3.5	0.8	12.5	16.7	2.5	10
Flat pea	22.5	5.5	15.3	1.8	6.2	0.8	6.3	7.6	1.6	11
Grama grass, black, growing (*Bouteloua eriopoda*) *	49.6	4.1	28.5	6.0	5.5	0.8	15.1	24.1	4.1	39
Grama grass, black, nearly mature	50.0	2.6	24.9	8.6	3.7	0.9	15.9	24.9	4.6	13
Grama grass, black, mature	64.6	2.0	30.2	14.1	4.1	1.0	21.7	33.6	4.[illegible]	12
Grama grass, blue, growing (*Bouteloua gracilis*) *	49.5	4.3	27.6	5.4	5.7	0.9	14.2	23.2	5.5	8
Grama grass, blue, nearly mature	64.6	2.4	28.1	10.7	5.2	1.0	18.9	31.2	8.3	17
Grama grass, blue, mature and weathered	85.0	0.4	33.7	83.3	3.0	0.9	32.8	41.6	6.7	2
Grapefruit *	13.6	0.3	11.6	37.7	1.1	0.6	1.4	10.0	0.5	1
Grasses, mixed, pasture	28.1	3.7	19.4	4.2	4.9	1.4	6.1	12.9	2.8	7
Grasses, mixed, hay stage	30.8	1.9	21.2	10.2	3.0	1.3	10.6	14.1	1.8	7
Grasses, mixed, in seed *	42.2	1.0	21.1	20.1	2.9	0.8	15.7	20.6	2.2	1
Grasses, mixed, second crop *	28.2	2.7	17.8	5.6	4.7	1.5	7.3	12.3	2.4	6
Greasewood *	50.0	7.3	23.3	2.2	10.4	1.3	12.8	18.0	7.5	1
Guinea grass	26.8	0.8	13.8	16.3	1.4	0.4	11.5	10.5	3.0	4
Honeysuckle, part eaten (*Lonicera Japonica*)	40.6	2.7	23.0	7.5	4.1	2.0	9.4	21.8	3.3	3
Horse bean fodder	17.4	2.7	11.6	3.3	3.5	0.5	4.1	7.6	1.7	8
Jack bean fodder *	23.2	4.0	14.2	2.6	5.2	0.5	6.4	8.4	2.7	1
Johnson grass pasture *	25.0	2.5	15.6	5.2	3.6	0.7	7.4	10.5	2.8	9
Johnson grass, in bloom *	35.0	1.5	20.6	12.7	2.8	0.8	11.4	16.5	3.5	10
Kafir fodder, all anal.*	23.6	1.2	14.4	11.0	2.4	0.7	6.6	12.0	1.9	56
Kafir fodder, heading out *	19.9	0.8	12.2	14.3	1.6	0.4	6.5	10.1	1.3	5
Kale	11.8	1.9	8.0	3.2	2.4	0.5	1.6	5.5	1.8	16
Kale, marrow-stem	13.8	1.8	10.0	4.6	2.2	0.4	2.2	7.1	1.9	6
Koa haole	29.4	3.9	17.5	3.5	5.3	0.6	9.7	12.2	1.8	20
Kohlrabi *	9.0	1.5	7.0	3.7	2.0	0.1	1.3	4.3	1.3	2
Kudzu *	30.6	4.2	19.9	3.7	5.5	1.0	8.3	13.6	2.2	1
Lespedeza, annual, pasture before bloom *	25.0	2.9	14.2	3.9	4.1	0.5	8.0	9.2	3.2	8
Lespedeza, annual, in bloom *	28.5	1.8	13.9	6.7	3.6	0.6	12.9	9.0	2.4	2
Lespedeza, annual, seed ripe *	37.2	1.6	15.6	8.8	5.1	0.9	16.1	12.2	2.9	2

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phos-phorus	Nitro-gen	Potas-sium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Fescue, sheep, pasture	0.10	0.08	0.90	0.37	..	..	..	..	..
Fescue, tall, young pasture	0.19	0.12	0.70	..	73	72	70	74	30
Fescue, tall, older	0.09	0.06	0.59	0.60	60	59	63	64	32
Fescues, native (*Festuca,* spp.)	0.13	0.09	0.56	..	..	..	..	..	..
Flat pea	0.11	0.11	0.99	..	88	65	49	73	12
Grama grass, black, growing (*Bouteloua eriopoda*)	0.16	0.07	0.88	..	..	..	..	..	..
[illegible] grass, black, [illegible] mature	0.15	0.06	0.59	..	69	47	56	50	4
Grama grass, black, mature	0.15	0.07	0.66	..	49	54	53	46	8
Grama grass, blue, growing (*Bouteloua gracilis*)	0.20	0.08	0.91	..	..	..	..	..	..
Grama grass, blue, nearly mature	0.14	0.08	0.83	..	46	30	55	47	8
Grama grass, blue, mature and weathered	0.24	0.06	0.48	..	14	14	51	39	8
Grapefruit	0.07	0.02	0.18	..	..	..	..	..	..
Grasses, mixed, pasture	..	0.09	0.78	0.66	75	42	74	77	9 †
Grasses, mixed, hay stage	0.17	0.07	0.48	0.41	63	50	70	74	22 †
Grasses, mixed, in seed	..	..	0.46	..	..	..	..	..	..
Grasses, mixed, second crop	0.25	0.10	0.75	0.36	..	..	..	..	..
Greasewood	0.49	0.10	1.66	..	..	..	..	..	..
Guinea grass	..	..	0.22	..	57	50	58	56	25 †
Honeysuckle, part eaten (*Lonicera Japonica*)	..	..	0.66	..	67	22	43	70	6
Horse bean fodder	0.16	0.05	0.56	0.36	78	62	54	78	10 †
Jack bean fodder	..	..	0.83	..	..	..	..	..	..
Johnson grass pasture	0.22	0.07	0.58	..	..	..	..	..	..
Johnson grass in bloom	0.29	0.06	0.45	..	..	..	..	..	..
Kafir fodder, all anal.	0.09	0.04	0.38	0.40	..	..	..	..	..
Kafir fodder, heading out	..	..	0.26	..	..	..	..	..	..
Kale	0.19	0.06	0.38	..	79	55	59	82	8
Kale, marrow-stem	..	..	0.35	..	80	60	67	88	41 †
Koa haole	..	..	0.85	..	74	33	36	79	7
Kohlrabi	0.08	0.07	0.32	0.37	..	..	..	..	..
Kudzu	0.96	0.07	0.88		..	..	..	..	..
Lespedeza, annual, pasture, before bloom	0.28	0.07	0.66	0.32	..	..	..	..	..
Lespedeza, annual, in bloom	0.33	0.06	0.58	0.30	..	..	..	..	..
Lespedeza, annual, seed ripe	0.38	0.06	0.82	0.34	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green Roughages, Roots, etc.—Cont.										
Lovegrass, weeping, pasture *	44.3	2.8	27.9	9.0	4.2	1.4	14.2	22.0	2.5	108
Lovegrass, weeping, more mature *	55.0	2.4	31.0	11.9	3.7	1.6	17.9	28.9	2.9	24
Lupine fodder, sweet	17.4	2.6	11.5	3.4	3.4	0.6	4.6	7.2	1.6	9
Mangels, roots	9.2	0.9	7.1	6.9	1.3	0.1	0.8	6.0	1.0	40
Melons, pie, or stock *	6.1	0.5	4.8	8.6	0.7	0.2	1.4	3.4	0.4	3
Mesquite grass, pasture, curly, (*Hilaria Belangeri*) *	35.0	2.1	20.6	8.8	3.4	0.7	9.6	16.6	4.7	3
Millet, foxtail varieties	29.9	1.8	18.7	9.4	2.9	0.8	9.4	14.3	2.5	34
Millet, Japanese, fodder	21.7	1.0	14.2	13.2	1.7	0.6	6.8	11.0	1.6	46
Millet, Japanese, pasture *	21.3	1.7	13.2	6.8	2.8	0.5	5.6	10.0	2.4	5
Millet, hog, or proso *	24.7	1.2	15.6	12.0	2.0	0.6	7.4	12.9	1.8	11
Millet, pearl, pasture *	20.6	1.3	12.8	8.8	2.1	0.6	6.4	9.6	1.9	21
Milo fodder *	22.7	0.7	13.0	17.6	1.8	0.4	7.0	12.1	1.4	9
Molasses grass (*Melinis minutiflora*)	39.0	0.3	20.2	66.3	1.3	0.9	16.0	18.0	2.8	4
Napier grass, immature	22.0	0.7	12.6	17.0	1.1	0.3	9.0	9.0	2.6	205
Napier grass, more mature *	27.1	0.7	14.8	20.1	1.2	0.6	10.4	11.9	3.0	12
Napier grass pasture, part eaten by stock	18.9	1.4	12.1	7.6	2.1	0.5	6.1	8.5	1.7	20
Oat grass, tall *	30.3	1.4	17.4	11.4	2.6	0.9	10.5	14.3	2.0	31
Oat pasture, before heading *	14.1	2.4	9.2	2.8	3.2	0.6	2.8	5.5	2.0	31
Oats, headed out	26.6	1.8	16.9	8.4	2.5	0.9	7.8	13.3	2.1	9
Oats, wild (*Avena fatua*) *	36.6	1.9	23.6	11.4	2.6	1.4	8.6	21.3	2.7	5
Oranges *	15.9	0.9	14.1	15.7	1.2	0.3	1.8	11.9	0.7	1
Orchard grass, young pasture	23.9	3.2	15.9	4.0	4.4	1.2	5.6	10.0	2.7	51
Orchard grass, heading	27.5	2.3	18.2	6.9	3.5	1.3	8.1	12.4	2.2	16
Orchard grass, in bloom	30.5	1.5	18.3	11.2	2.6	1.0	10.7	13.9	2.3	28
Para grass	27.8	1.0	14.9	13.9	1.8	0.4	10.0	12.7	2.9	8
Parsnips, roots *	16.6	1.2	14.8	11.3	1.7	0.4	1.3	11.9	1.3	2
Pasture grasses and legumes, mixed, from well-grazed, fertile pasture, northern states	22.0	3.8	15.0	2.9	5.0	0.9	4.8	9.4	1.9	703
Pasture grasses and legumes, mixed, from well-grazed, fertile pasture, southern states *	25.1	2.9	16.7	4.8	3.8	0.8	6.7	11.3	2.5	1201
Pasture grasses, with small proportion of legumes, fertile pasture, northern states	22.0	2.8	14.6	4.2	3.8	1.0	5.3	9.9	2.0	183

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Lovegrass, weeping, pasture	0.14	0.08	0.67	..	..	..	..	..	..
Lovegrass, weeping, more mature	0.12	0.06	0.59	..	..	..	..	..	..
Lupine fodder, sweet	..	0.04	0.54	0.42	75	52	61	75	29 †
Mangels, roots	0.02	0.02	0.21	0.21	66	0	69	94	71
Melons, pie, or stock	..	..	0.11	..	..	..	..	..	..
Mesquite grass, pasture, curly, (*Hilaria Belangeri*)	0.17	0.06	0.54	..	..	..	..	..	..
Millet, foxtail varieties	0.10	0.06	0.46	0.58	61	59	67	67	12 †
Millet, Japanese, fodder	0.11	0.07	0.27	0.52	60	62	69	70	9
Millet, Japanese, pasture	..	..	0.45	..	..	..	..	..	..
Millet, hog, or proso	..	..	0.32	..	..	..	..	..	..
Millet, pearl, pasture	..	..	0.34	..	..	..	..	..	..
Milo fodder	0.09	0.05	0.29	0.62	..	..	..	..	..
Molasses grass (*Melinis minutiflora*)	..	..	0.21	..	24	45	58	54	22
Napier grass, immature	0.08	0.07	0.18	..	62	58	64	64	72 †
Napier grass, more mature	..	..	0.19	..	..	..	..	..	..
Napier grass pasture, part eaten by stock	0.09	0.07	0.34	..	65	58	68	70	4
Oat grass, tall	0.12	0.14	0.42	0.91	..	..	..	..	..
Oat pasture, before heading	0.06	0.09	0.51	..	..	..	..	..	..
Oats, headed out	0.09	0.09	0.40	0.50	73	64	61	68	7 †
Oats, wild (*Avena fatua*)	0.09	0.10	0.42	..	..	..	..	..	..
Oranges	0.09	0.02	0.19	..	..	..	..	..	..
Orchard grass, young pasture	0.13	0.12	0.70	0.63	72	50	74	72	84
Orchard grass, heading	0.07	0.08	0.56	..	66	45	73	70	72
Orchard grass, in bloom	0.07	0.07	0.42	..	58	42	69	61	11
Para grass	0.11	0.11	0.29	0.44	56	62	56	61	26 †
Parsnips, roots	0.06	0.08	0.27	0.52	..	..	..	..	..
Pasture grasses and legumes, mixed, from well-grazed, fertile pasture, northern states	0.14	0.08	0.80	0.53	75	51	73	71	33
Pasture grasses and legumes, mixed, from well-grazed, fertile pasture, southern states	0.19	0.09	0.61	0.37	..	..	..	..	..
Pasture grasses, with small proportion of legumes, fertile pasture, northern states	0.12	0.07	0.61	0.38	74	51	73	68	38

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. pro-tein	Total dig. nutri-ents	Nutri-tive ratio	Average total composition: Pro-tein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Pasture grasses, with small proportion of legumes, fertile pasture, southern states *	25.0	2.4	15.7	5.5	3.2	0.7	6.5	11.5	3.1	29
Pasture grasses, from closely-grazed poor to fair pasture, northern states	30.2	3.2	18.1	4.7	4.7	0.8	6.5	14.5	3.7	40
Pasture, temporary winter, southern states *	17.0	3.8	11.9	2.1	5.1	0.9	2.4	7.4	1.2	1
Pasture grasses and clovers at hay stage	33.0	2.5	19.8	6.9	3.4	0.9	9.8	16.6	2.[illegible]	34
Pasture grasses, western plains, active growth	35.0	2.3	21.0	8.1	3.5	0.9	11.1	16.9	2.[illegible]	46 5
Pasture grasses, western plains, late summer	50.0	1.4	24.7	16.6	2.6	1.2	17.0	25.8	3.4	47
Pasture grasses, western plains, mature	65.0	1.1	30.5	26.7	2.6	1.1	22.9	34.2	4.2	36
Pasture grasses, western plains, mature and weathered	90.8	0.5	40.9	80.8	2.7	1.6	33.7	45.6	7.2	82
Peas, field	17.3	2.9	12.2	3.2	3.5	0.6	4.3	7.3	1.6	46
Pea pods	12.9	1.0	9.4	8.4	1.8	0.3	3.0	6.9	0.9	1
Peas and barley	20.2	2.7	12.5	3.6	3.6	0.8	5.2	8.9	1.7	11
Peas and oats	22.7	2.4	14.4	5.0	3.2	0.9	6.4	10.3	1.9	54
Peas, oats, and rape *	17.9	2.3	10.7	3.7	3.1	0.8	4.3	7.0	2.7	3
Pigeon pea	41.7	3.3	24.5	6.4	5.2	1.7	16.9	16.0	1.9	18
Pineapple tops *	16.0	0.9	8.4	8.3	1.6	0.5	3.7	8.7	1.5	3
Potatoes, tubers	21.2	1.3	17.4	12.4	2.2	0.1	0.4	17.4	1.1	469
Potato peelings	21.2	0.8	16.8	20.0	2.1	0.1	0.7	17.0	1.3	1
Potato pomace, wet *	8.3	0	6.1	..	0.7	0.1	0.9	6.3	0.3	2
Prickly comfrey *	12.8	2.0	8.2	3.1	2.5	0.3	1.8	5.9	2.3	20
Pumpkins, field, entire	10.4	1.3	9.0	5.9	1.7	1.0	1.6	5.2	0.9	8
Pumpkins, with seeds and inside tissue removed	7.3	1.1	6.9	5.3	1.2	0.2	1.1	4.3	0.5	3
Purslane *	10.3	1.7	6.6	2.9	2.2	0.3	1.5	4.4	1.9	3
Quack grass pasture	24.7	3.0	16.8	4.6	3.9	1.1	7.1	10.3	2.3	8
Quack grass, hay stage	32.0	1.5	18.1	11.1	2.3	0.9	11.3	15.7	1.8	6
Rape	16.3	2.4	12.8	4.3	2.9	0.6	2.6	8.0	2.2	40
Rape, leaves and leaf stalks *	15.4	3.5	12.4	2.5	4.3	0.6	1.0	7.9	1.6	3
Red top, pasture *	26.0	3.6	17.5	3.9	4.9	1.1	5.7	11.6	2.7	36
Red top, in bloom	39.0	1.8	23.0	11.8	2.9	1.1	12.6	19.8	2.6	8
Reed canary grass pasture *	25.0	3.0	15.3	4.1	4.3	1.1	5.5	11.6	2.5	2
Reed canary grass, hay stage *	30.0	1.3	15.2	10.7	2.0	0.8	10.5	15.0	1.7	3
Rescue grass, pasture *	28.9	3.9	20.2	4.2	5.0	1.0	6.7	12.2	4.0	9

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Pasture grasses, with small proportion of legumes, fertile pasture, southern states	0.15	0.08	0.51	0.25	..	..	..	..	..
Pasture grasses, from closely-grazed poor to fair pasture, northern states	0.14	0.04	0.75	0.25	68	51	70	65	14
Pasture, temporary winter, southern states	..	..	0.82	..	..	..	..	..	..
Mi[illegible] grasses and clo-[illegible]t hay stage	..	..	0.54	..	74	35	54	68	9
Mille[illegible] grasses, western Mill[illegible], active growth	0.11	0.05	0.56	..	65	52	66	61	18
Pasture grasses, western plains, late summer	0.15	0.05	0.42	..	54	41	56	49	24
Pasture grasses, western plains, mature	0.20	0.03	0.42	..	44	52	54	46	16
Pasture grasses, western plains, mature and weathered	0.28	0.04	0.43	..	20	18	57	45	20
Peas, field	0.21	0.04	0.56	0.26	84	58	62	80	14 †
Pea pods	0.19	0.03	0.29		53	57	79	83	8 †
Peas and barley	0.16	0.07	0.58	0.30	75	59	52	68	4
Peas and oats	0.17	0.07	0.51	0.38	74	64	59	68	10
Peas, oats, and rape	..	0.07	0.50	0.37	..	..	..	..	..
Pigeon pea	..	..	0.83	..	64	62	42	73	20
Pineapple tops	..	..	0.26	..	..	..	..	..	..
Potatoes, tubers	0.01	0.05	0.35	0.48	59	26	0	92	17 †
Potato peelings	0.03	0.04	0.34	..	40	39	14	93	2 †
Potato pomace, wet	0.01	0.03	0.11	0.11	..	..	..	..	..
Prickly comfrey	..	0.07	0.40	0.58	..	..	..	..	..
Pumpkins, field, entire	..	0.04	0.27	0.27	75	92	63	89	9
Pumpkins, with seeds and inside tissue removed	0.02	0.04	0.19	0.26	93	93	100	100	2
Purslane	..	0.04	0.35	0.94	..	..	..	..	..
Quack grass pasture	0.09	0.08	0.62	..	78	40	75	72	3
Quack grass, hay stage	0.09	0.07	0.37	..	66	49	53	61	9
Rape	0.24	0.07	0.46	0.55	82	50	87	93	13 †
Rape, leaves and leaf stalks	..	..	0.69	..	..	..	..	..	..
Red top, pasture	0.17	0.10	0.78	0.55	..	..	..	..	..
Red top, in bloom	0.13	0.09	0.46	0.83	61	50	61	62	3
Reed canary grass pasture	0.08	0.09	0.69	..	..	..	..	..	..
Reed canary grass, hay stage	0.08	0.06	0.32	..	..	..	..	..	..
Rescue grass, pasture	0.15	0.08	0.80	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Rescue grass, heading *	30.0	2.8	20.1	6.2	4.2	1.0	9.2	13.4	2.2	1
Rhodes grass	25.3	1.1	15.1	12.7	1.8	0.4	9.5	10.8	2.8	13
Rushes, western (*Juncus*, spp.) * ...	31.1	2.2	19.2	7.7	3.4	0.6	9.8	15.1	2.2	11
Russian thistle *	30.0	2.2	13.0	4.9	3.4	0.6	9.0	12.5	4.5	12
Rutabagas, roots	11.1	1.0	9.5	8.5	1.3	0.2	1.4	7.2	1.0	11
Rye pasture *	19.5	4.0	12.8	2.2	5.3	0.9	3.4	7.5	2.4	31
Rye fodder	22.3	2.1	16.3	6.8	2.6	0.8	7.6	9.6	1.7	41
Rye grass, Italian * ...	27.1	1.9	18.3	8.6	3.1	1.3	6.8	13.4	2.5	25
Rye grass, Italian, pasture *	20.0	2.9	12.1	3.2	3.9	0.8	4.0	7.5	3.8	16
Rye grass, perennial ..	26.6	1.9	18.0	8.5	3.0	1.3	6.7	13.2	2.4	5
Rye grass, perennial, young pasture *	20.0	4.1	12.4	2.0	5.4	0.8	3.6	6.8	3.4	6
Sagebrush	51.3	5.0	26.6	4.3	6.6	4.7	12.7	22.3	5.0	12
Sagebrush leaves * ...	50.0	3.5	31.6	8.0	8.4	7.9	6.3	24.0	3.4	3
Saint Augustine grass, pasture *	18.1	1.9	11.4	5.0	2.7	0.5	5.4	8.2	1.3	3
Saltbush, Australian ..	23.3	3.1	10.6	2.4	3.7	0.4	4.4	9.4	5.4	7
Saltbush leaves *	28.0	2.8	12.1	3.3	4.2	0.6	3.4	12.3	7.5	18
Saltbush winter range .	85.0	2.8	39.2	13.0	6.7	4.0	24.4	34.8	15.1	..
Saltbushes, miscellaneous	28.9	1.8	9.2	4.1	2.8	0.5	7.8	12.5	5.3	15
Sanfoin (*Onobrychis viciaefolia*)	25.6	2.8	16.3	4.8	3.8	0.8	6.2	12.4	2.4	4
Serradella *	20.2	2.2	12.2	4.5	2.9	0.7	4.8	8.8	3.0	8
Sorghum fodder, sweet	24.9	0.8	17.3	20.6	1.5	1.0	7.0	14.0	1.4	94
Sotol heads, or bulbs ..	39.7	0.9	24.8	26.6	2.2	0.6	10.4	24.8	1.7	7
Soybean forage, all analyses	24.0	3.2	15.2	3.8	4.1	1.0	6.6	9.9	2.4	268
Soybeans, before bloom *	20.0	2.4	12.8	4.3	3.2	1.0	5.9	8.1	1.8	23
Soybeans, in bloom ...	20.8	3.0	12.9	3.3	3.9	0.6	5.8	8.2	2.3	8
Soybeans, seeds forming *	24.2	3.1	15.5	4.0	4.0	1.0	6.4	10.4	2.4	21
Soybeans, seed well developed	29.0	3.7	19.6	4.3	4.7	1.7	8.3	11.7	2.6	22
Soybeans and corn, ⅓ or more soybeans * ..	23.1	1.8	15.3	7.5	2.8	0.8	5.3	12.5	1.7	7
Soybeans and corn, small proportion of soybeans *	26.7	1.3	18.2	13.0	2.2	0.8	6.3	15.9	1.5	5
Soybeans and millet * .	23.5	1.5	15.1	9.1	2.3	0.5	7.5	11.4	1.8	7
Soybeans and pearl millet, pasture *	24.5	2.7	15.9	4.9	4.2	0.9	6.4	11.1	1.9	32
Soybeans and Sudan grass *	24.2	2.0	15.9	7.0	2.7	0.5	8.3	11.1	1.6	7
Spanish moss *	41.0	0	24.4	..	1.9	0.9	12.1	23.1	3.0	..
Sudan grass, pasture ..	21.6	2.4	14.3	5.0	3.3	0.6	5.6	10.2	1.9	5
Sudan grass, headed to in bloom	23.4	1.4	15.4	10.0	1.9	0.4	8.4	10.3	2.4	30

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Rescue grass, heading	..	..	0.67	..	..	..	..	..	..
Rhodes grass	0.16	0.10	0.29	0.58	59	40	74	62	12
Rushes, western (*Juncus*, spp.)	..	..	0.54	..	..	..	..	..	..
Russian thistle	0.66	0.07	0.54	2.05	..	..	..	..	..
Rutabagas, roots	0.05	0.03	0.21	0.21	75	79	89	96	6 †
Rye pasture	0.13	0.10	0.85	..	..	..	..	..	..
Rye fodder	0.08	0.07	0.42	..	79	74	80	71	2
Rye grass, Italian	..	..	0.50	..	..	..	..	..	..
Rye grass, Italian, pasture	0.13	0.08	0.62	0.40	..	..	..	..	..
Rye grass, perennial	0.12	0.07	0.48	0.51	62	62	70	73	9 †
Rye grass, perennial, young pasture	0.13	0.08	0.86	0.38	..	..	..	..	..
Sagebrush	0.52	0.13	1.06	..	75	..	..	71	4
Sagebrush leaves	..	..	1.34	..	..	..	..	..	..
Saint Augustine grass pasture	..	..	0.43	..	..	..	..	..	..
Saltbush, Australian	0.19	0.03	0.59	..	85	24	27	64	2
Saltbush leaves	..	..	0.67	..	..	..	..	..	..
Saltbush winter range	2.01	0.08	1.07	..	42	66	45	56	..
Saltbushes, miscellaneous	0.58	0.03	0.45	..	66	52	8	49	3
Sanfoin (*Onobrychis viciaefolia*)	..	..	0.61	..	73	67	42	78	2
Serradella	0.28	0.09	0.46	0.43	..	..	..	..	..
Sorghum fodder, sweet	0.09	0.03	0.24	0.36	56	70	62	75	6
Sotol heads, or bulbs	..	..	0.35	..	40	3	36	81	..
Soybean forage, all analyses	0.26	0.07	0.66	0.22	77	62	51	74	38
Soybeans, before bloom	..	..	0.51	..	..	..	..	..	..
Soybeans, in bloom	0.36	0.06	0.62	0.22	76	55	55	73	16
Soybeans, seeds forming	0.37	0.07	0.64	0.21	..	..	..	..	..
Soybeans, seed well developed	0.38	0.09	0.75	0.23	79	81	56	70	10
Soybeans and corn, ⅓ or more soybeans	0.13	0.06	0.45	0.32	..	..	..	..	..
Soybeans and corn, small proportion of soybeans	0.08	0.05	0.35	0.36	..	..	..	..	..
Soybeans and millet	..	..	0.37	..	..	..	..	..	..
Soybeans and pearl millet, pasture	..	..	0.67	..	..	..	..	..	..
Soybeans and Sudan grass	..	..	0.43	..	..	..	..	..	..
Spanish moss	..	..	0.30	..	..	..	..	..	..
Sudan grass, pasture	0.12	0.10	0.53	..	72	70	74	67	6 †
Sudan grass, headed to in bloom	0.09	0.07	0.30	0.34	72	72	76	68	4 †

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green Roughages, Roots, etc.—Cont.										
Sudan grass, in seed *	28.5	1.0	18.6	17.6	1.7	0.5	9.6	14.6	2.1	3
Sugar cane	23.2	0.6	14.1	22.5	1.0	0.8	6.8	13.4	1.2	11
Sugar cane, leaves and tops (strip cane)	25.7	0.6	12.5	19.8	1.3	0.4	8.4	12.3	3.3	4
Sugar cane, Japanese *	28.2	0.4	17.1	41.8	0.7	0.5	7.7	18.2	1.1	3
Sunflowers, Russian, whole plant	16.9	0.8	10.6	12.3	1.4	0.7	5.2	7.9	1.7	40
Sunflowers and corn * .	18.2	0.8	10.9	12.6	1.4	0.6	6.1	8.5	1.6	2
Sweet potatoes, roots *	31.8	0.2	25.6	127.0	1.6	0.4	1.9	26.7	1.2	31
Sweet vernal grass pasture (*Anthoxanthum oderatum*) *	22.0	3.1	13.5	3.4	4.4	1.0	3.9	10.5	2.2	21
Switch grass, active growth (*Panicum virgatum*) *	38.5	2.5	23.3	8.3	3.8	0.8	11.8	19.8	2.3	1
Switch grass, mature *	42.0	1.0	20.5	19.5	2.3	1.1	18.2	18.1	2.3	2
Switch grass, mature and weathered * ...	90.0	0.3	42.5	140.7	1.7	1.6	37.2	45.1	4.4	2
Teosinte *	21.3	1.0	13.5	12.5	1.7	0.5	6.7	10.4	2.0	19
Timothy, young pasture	23.9	3.5	16.5	3.7	4.7	0.9	4.6	11.1	2.6	105
Timothy, before bloom	24.7	1.5	15.9	9.6	2.6	0.9	7.6	12.0	1.6	22
Timothy, in bloom ...	31.5	1.5	19.4	11.9	2.7	0.9	10.5	15.5	1.9	27
Timothy, in seed	46.4	1.1	23.7	20.5	3.0	1.3	15.3	24.5	2.3	15
Tobosa grass, active growth (*Hilaria mutica*)	39.6	3.2	21.6	5.8	4.2	0.6	12.3	17.3	5.2	15
Tobosa grass, nearly to fully mature	50.0	1.7	22.1	12.0	3.2	1.0	17.0	22.9	5.9	2
Tomatoes, whole fruit *	5.7	0.6	4.9	7.2	0.9	0.4	0.6	3.3	0.5	24
Tomato pomace *	11.1	0.9	6.9	6.7	2.3	1.2	2.8	4.3	0.5	1
Trefoil, yellow, or black medic (*Medicago lupulina*) *	22.7	3.4	13.8	3.1	4.5	0.8	5.6	9.5	2.3	2
Turnips	9.3	0.9	7.8	7.7	1.3	0.2	1.1	5.8	0.9	21
Turnip tops	15.0	1.8	10.6	4.9	2.8	0.4	1.5	7.3	3.0	5
Velvet bean forage ...	17.9	2.5	11.5	3.6	3.5	0.7	5.1	6.6	2.0	1
Vetch, common	20.4	2.9	12.1	3.2	3.8	0.5	5.5	8.5	2.1	14
Vetch, hairy	18.2	3.5	12.3	2.5	4.2	0.5	5.0	6.3	2.2	21
Vetches, wild (*Vicia*, spp.) *	24.6	3.8	14.7	2.9	5.1	0.5	6.9	10.0	2.1	6
Vetch and oats fodder	26.5	2.9	17.1	4.9	3.8	0.9	7.5	12.0	2.3	15
Vetch and oats pasture	25.0	4.1	14.8	2.6	5.4	0.9	5.0	9.7	4.0	4
Vetch and wheat fodder	29.7	2.5	20.1	7.0	3.4	0.6	8.4	15.2	2.1	9
Wheat fodder *	31.9	1.5	16.5	10.0	2.7	0.8	8.9	17.2	2.3	12
Wheat pasture *	19.8	3.6	12.7	2.5	4.8	0.8	3.8	7.6	2.8	36
Wheatgrass, crested, very young	25.1	5.6	18.9	2.4	6.6	0.9	5.2	9.7	2.7	9
Wheatgrass, crested, young	34.3	2.7	23.1	7.6	4.0	0.9	8.9	17.8	2.7	3

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages, Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Sudan grass, in seed	0.09	0.06	0.27	..	..	..	..	..	..
Sugar cane	..	0.04	0.16	0.37	57	51	61	63	12 †
Sugar cane, leaves and tops (strip cane)	0.09	0.07	0.21	0.76	43	49	58	54	20
Sugar cane, Japanese	0.10	0.04	0.11	0.18	..	..	..	..	..
Sunflowers, Russian, whole plant	0.29	0.04	0.22	0.63	59	64	50	78	30 †
Sunflowers and corn	..	..	0.22	..	..	..	..	..	..
Sweet potatoes, roots	0.03	0.04	0.26	0.38	..	..	..	..	..
Sweet vernal grass pasture, (*Anthoxanthum odoratum*)	0.14	0.08	0.70	..	..	..	..	..	..
Switch grass, active growth (*Panicum virgatum*)	..	..	0.61	..	..	..	..	..	..
Switch grass, mature	..	..	0.37	..	..	..	..	..	..
Switch grass, mature and weathered	0.25	0.03	0.27	..	..	..	..	..	..
Teosinte	..	..	0.27	..	..	..	..	..	..
Timothy, young pasture	0.14	0.09	0.75	0.50	74	54	73	77	3
Timothy, before bloom	0.07	0.07	0.42	..	57	54	68	68	30
Timothy, in bloom	0.08	0.08	0.43	0.54	54	54	62	67	24
Timothy, in seed	0.08	0.09	0.48	0.73	36	54	48	56	6
Tobosa grass, active growth (*Hilaria mutica*)	0.12	0.08	0.67	..	75	55	62	58	4
Tobosa grass, nearly to fully mature	0.13	0.07	0.51	..	53	47	52	46	8
Tomatoes, whole fruit	0.01	0.03	0.14	0.27	..	..	..	..	..
Tomato pomace	..	..	0.37	..	..	..	..	..	..
Trefoil, yellow, or black medic (*Medicago lupulina*)	..	..	0.72	..	..	..	..	..	..
Turnips	0.06	0.02	0.21	0.26	71	64	94	95	7 †
Turnip tops	0.49	0.06	0.45	0.45	..	64	96	93	4 †
Velvet bean forage	..	0.06	0.56	0.37	70	66	58	77	28 †
Vetch, common	0.27	0.07	0.61	0.51	75	49	40	76	12 †
Vetch, hairy	0.20	0.06	0.67	0.41	83	72	64	77	14
Vetches, wild (*Vicia*, spp.)	..	..	0.82	..	..	..	..	..	..
Vetch and oats fodder	0.18	0.08	0.61	0.45	75	47	68	68	3
Vetch and oats pasture	0.10	0.13	0.86	..	76	64	63	64	13 †
Vetch and wheat fodder	..	..	0.54	..	74	57	68	73	5
Wheat fodder	0.05	0.07	0.43	..	..	..	..	..	..
Wheat pasture	0.09	0.08	0.77	..	..	..	..	..	..
Wheatgrass, crested, very young	0.12	0.08	1.06	..	85	62	79	82	4
Wheatgrass, crested, young	0.14	0.07	0.64	..	67	59	66	75	12

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green Roughages, Roots, etc.—Cont.										
Wheatgrass, crested, headed out *	**36.9**	**1.6**	**21.1**	12.2	2.7	0.6	12.2	18.7	2.7	2
Wheatgrass, crested, mature *	**60.0**	**1.7**	**32.2**	17.9	3.3	1.2	23.2	28.8	3.5	5
Wheatgrass, crested, mature and weathered	**81.0**	**1.2**	**42.8**	34.7	2.7	1.2	31.7	42.0	3.4	5
Wheatgrass, western, young *	**35.0**	**4.0**	**22.6**	4.7	6.0	1.4	9.1	14.3	4.2	4
Wheatgrass, western, mature	**65.0**	**0.8**	**32.2**	39.3	2.8	2.4	20.9	30.5	8.4	1
Wheatgrasses, misc. (*Agropyron,* spp.) *	**46.9**	**2.5**	**27.3**	9.9	4.1	1.3	16.5	21.6	3.4	21
Winter fat (*Eurotia lanata*) *	**65.0**	**2.5**	**35.0**	13.0	5.5	1.3	23.7	28.5	6.0	4
Wire grasses, western *	**38.9**	**1.9**	**23.4**	11.3	3.8	0.9	13.3	18.6	2.3	4
Yucca (bear grass)	**49.4**	**1.4**	**27.5**	18.6	3.8	1.0	21.1	20.0	3.5	2
Yucca (soapweed)	**44.6**	**0.9**	**23.4**	25.0	2.4	0.8	14.1	24.0	3.3	22
Yucca (soapweed), leaves *	**56.2**	**1.7**	**28.4**	15.7	4.4	1.7	18.7	27.7	3.7	8
Silages										
Alfalfa, not wilted, no preservative	**24.7**	**2.6**	**13.5**	4.2	4.1	0.9	8.2	9.2	2.3	30
Alfalfa, wilted	**36.2**	**4.3**	**21.5**	4.0	6.3	1.4	11.4	13.9	3.2	35
Alfalfa-molasses, not wilted	**26.8**	**2.7**	**15.4**	4.7	4.1	0.9	8.2	11.2	2.4	25
Alfalfa-molasses, wilted	**35.8**	**4.0**	**20.9**	4.2	6.0	1.1	10.9	14.7	3.1	33
Alfalfa, not wilted, grain added *	**25.5**	**2.6**	**15.2**	4.8	3.8	1.2	7.5	10.6	2.4	1
Alfalfa-phosphoric acid	**26.8**	**3.2**	**14.7**	3.6	4.7	0.9	8.5	10.2	2.5	14
Alfalfa-brome, not wilted	**25.0**	**2.6**	**17.0**	5.5	3.8	1.1	7.7	10.3	2.1	6
Alfalfa-brome, wilted greatly *	**44.9**	**4.8**	**29.5**	5.1	7.0	1.0	15.0	17.8	4.1	2
Alfalfa-grass, over half alfalfa, wilted *	**36.2**	**4.1**	**21.2**	4.2	6.1	1.1	11.4	14.4	3.2	6
Alfalfa-timothy-molas.*	**27.5**	**2.7**	**15.9**	4.9	4.1	1.2	9.1	10.7	2.4	3
Apple-alfalfa	**24.7**	**1.1**	**14.5**	12.2	2.2	0.8	6.8	13.2	1.7	2
Apple pomace *	**20.9**	**0.6**	**14.3**	22.8	1.6	1.3	4.4	12.6	1.0	15
Atlas sorghum	**29.7**	**1.4**	**18.5**	12.2	2.5	0.8	7.4	16.7	2.3	22
Atlas sorghum stover *	**26.8**	**0.6**	**15.8**	25.3	1.5	0.5	6.7	16.4	1.7	2
Barley *	**25.0**	**1.4**	**12.7**	8.1	2.6	1.0	9.4	9.4	2.6	20
Bean vines, lima *	**27.3**	**2.1**	**14.2**	5.8	3.3	0.8	8.1	11.1	4.0	2
Beet pulp, ensiled	**12.0**	**1.0**	**9.0**	8.0	1.7	0.4	5.2	4.3	0.4	2
Beet top, sugar, much dirt adhering	**31.6**	**2.5**	**14.9**	5.0	3.8	0.6	3.9	10.8	12.5	62
Berseem, or Egyptian clover	**24.1**	**1.9**	**9.6**	4.1	4.1	0.9	7.8	7.7	3.6	4
Bluegrass with some white clover, molasses added	**35.0**	**4.8**	**23.5**	3.9	6.8	1.8	8.9	13.9	3.6	2

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Green Roughages Roots, etc.—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Wheatgrass, crested, headed out	..	..	0.43	..	..	..	..	..	..
Wheatgrass, crested, mature	0.15	0.08	0.53	..	..	..	..	..	..
Wheatgrass, crested, mature and weathered	0.16	0.07	0.43	..	46	36	59	52	4
Wheatgrass, western, young	0.12	0.06	0.96	..	..	..	..	..	..
Wheatgrass, western, mature	0.21	0.10	0.45	..	30	51	58	54	4
Wheatgrasses, misc. (*Agropyron,* spp.)	..	..	0.66	..	..	..	..	..	..
Winter fat (*Eurotia lanata*)	1.04	0.08	0.88	..	..	..	..	..	..
Wire grasses, western	..	..	0.61	..	..	..	..	..	..
Yucca (bear grass)	..	..	0.61	..	36	0	65	62	2
Yucca (soapweed)	0.41	0.08	0.38	..	38	0	35	73	7
Yucca (soapweed), leaves	..	..	0.70	..	..	..	..	..	..
Silages									
Alfalfa, not wilted, no preservative	0.35	0.08	0.66	0.58	64	58	50	61	8
Alfalfa, wilted	0.51	0.12	1.01	0.84	68	65	55	64	8
Alfalfa-molasses, not wilted	0.41	0.08	0.66	0.71	66	60	47	68	22
Alfalfa-molasses, wilted	0.55	0.11	0.96	0.95	67	61	51	67	29
Alfalfa, not wilted, grain added	..	..	0.61	..	..	..	..	..	..
Alfalfa-phosphoric acid	0.37	0.30	0.75	0.63	69	46	46	65	21
Alfalfa-brome, not wilted	0.37	0.05	0.61	..	69	66	70	71	18
Alfalfa-brome, wilted greatly	0.66	0.10	1.12	..	..	..	..	..	..
Alfalfa-grass, over half alfalfa, wilted	..	..	0.98	..	..	..	..	..	..
Alfalfa-timothy-molasses	..	..	0.66	..	..	..	..	..	..
Apple-alfalfa	..	..	0.35	..	51	47	49	70	6
Apple pomace	0.02	0.02	0.26	0.10	..	..	..	..	..
Atlas sorghum	0.12	0.06	0.40	0.33	55	55	58	71	2
Atlas sorghum stover	..	..	0.24	..	..	..	..	..	..
Barley	0.08	0.08	0.42	0.39	..	..	..	..	..
Bean vines, lima	..	..	0.53	..	..	..	..	..	..
Beet pulp, ensiled	..	..	0.27	..	61	0	87	81	4
Beet top, sugar, much dirt adhering	0.31	0.07	0.61	1.80	67	40	82	80	43
Berseem, or Egyptian clover	..	..	0.66	..	46	59	38	46	8
Bluegrass with some white clover, molasses added	..	..	1.09	..	70	71	72	68	6

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Silages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Broom corn stover	**26.7**	**0.5**	**13.2**	25.4	1.3	0.4	9.5	13.3	2.2	3
Citrus pulp, pressed * .	**22.8**	**0.4**	**20.0**	49.0	1.7	2.4	3.5	13.9	1.3	1
Clover, Ladino, and grass	**29.9**	**3.9**	**21.4**	4.5	5.4	1.5	7.5	12.9	2.6	7
Clover, red, not wilted .	**29.5**	**2.4**	**17.3**	6.2	3.7	0.9	9.8	12.6	2.5	4
Clover, red, molasses ..	**32.8**	**2.4**	**20.6**	7.6	4.5	1.0	9.8	14.8	2.7	7
Clover, red, and grass, wilted	**35.1**	**2.5**	**22.2**	7.9	4.3	1.1	11.0	15.7	3.0	6
Clover, sweet *	**28.0**	**3.4**	**15.7**	3.6	4.5	0.9	9.6	10.5	2.5	10
Clover, sweet, wilted ..	**39.9**	**6.0**	**22.5**	2.8	7.9	1.3	12.7	14.0	4.0	13
Corn, dent, well-matured, recent analyses	**27.6**	**1.2**	**18.3**	14.3	2.3	0.8	6.7	16.2	1.6	393
Corn, dent, well-matured, well-eared ...	**28.5**	**1.3**	**19.8**	14.2	2.3	0.9	6.3	17.4	1.6	37
Corn, dent, well-matured, fair in ears ...	**26.3**	**1.1**	**17.2**	14.6	2.1	0.8	7.0	14.7	1.7	123
Corn, dent, well-matured, few ears	**26.3**	**1.1**	**16.2**	13.7	2.2	0.8	8.5	12.9	1.9	33
Corn, dent, immature, before dough stage ..	**20.3**	**0.9**	**12.9**	13.3	1.8	0.6	5.8	10.8	1.3	81
Corn, dent, immature, southern-type corn ..	**19.4**	**0.8**	**12.0**	14.0	1.6	0.5	6.0	10.2	1.1	23
Corn, dent, drouth-stricken corn *	**24.6**	**1.4**	**15.0**	9.7	2.6	0.5	6.4	12.9	2.2	2
Corn stover silage from mature dent corn, ears removed	**23.7**	**0.6**	**14.0**	22.3	1.6	0.7	7.8	12.0	1.6	11
Corn, flint	**23.4**	**0.9**	**16.5**	17.3	1.6	0.6	5.4	14.3	1.5	10
Corn ears, snapped, immature	**44.8**	**2.2**	**33.0**	14.0	4.0	1.7	5.8	32.3	1.0	7
Corn, sweet	**24.2**	**1.5**	**15.8**	9.5	2.3	0.8	6.9	12.2	2.0	14
Corn and sorghum * ..	**26.0**	**1.0**	**16.4**	15.4	1.9	0.8	7.1	14.8	1.4	1
Corn and soybeans, mostly corn *	**26.1**	**1.4**	**17.0**	11.1	2.5	0.9	6.8	14.2	1.7	20
Corn and soybeans, well-matured, 30% or more soybeans	**28.3**	**2.0**	**19.7**	8.9	3.2	1.2	7.3	14.2	2.4	10
Corn-canning factory waste, (husks, cobs, and waste ears)	**22.4**	**1.1**	**16.1**	13.6	2.0	1.0	5.6	12.8	1.0	2
Cowpea, wilted	**30.0**	**2.6**	**17.8**	5.8	4.5	1.2	8.5	12.5	3.3	13
Crotalaria intermedia ..	**23.5**	**1.9**	**9.6**	4.1	3.0	0.7	10.6	7.8	1.4	51
Darso	**26.9**	**1.0**	**15.6**	14.6	1.9	0.3	6.5	16.7	1.5	1
Durra *	**29.9**	**0.9**	**16.6**	17.4	1.8	1.0	10.3	14.0	2.8	3
Fescue, tall	**33.5**	**2.6**	**20.7**	7.0	4.3	1.2	9.6	14.8	3.6	2
Feterita *	**30.0**	**1.4**	**17.1**	11.2	2.6	0.7	6.0	18.6	2.1	1
Grass silage, considerable legumes *	**25.6**	**2.0**	**15.5**	6.8	3.6	0.9	8.6	10.8	1.7	2
Grass silage, considerable legumes, wilted	**33.3**	**2.9**	**19.1**	5.6	5.2	1.3	8.8	14.2	3.8	7

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phos-phorus	Nitro-gen	Potas-sium	Protein	Fat	Fiber	N-free extract	No. of trials
Silages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Broom corn stover	..	..	0.21	..	36	69	50	55	1
Citrus pulp, pressed ...	..	..	0.27	..	..	..	..	..	..
Clover, Ladino, and grass	0.31	0.07	0.86	..	72	58	65	83	5
Clover, red, not wilted .	0.50	0.07	0.59	0.53	64	58	57	65	44 †
Clover, red, molasses ..	..	..	0.72	..	54	65	65	70	2
Clover, red, and grass, wilted	0.39	0.07	0.69	..	59	66	68	67	61 †
Clover, sweet	0.39	0.07	0.72	0.55	..	..	..	..	..
Clover, sweet, wilted ..	0.55	0.10	1.26	0.78	76	61	42	67	11
Corn, dent, well-matured, recent analyses	0.10	0.07	0.37	0.30	54	75	65	70	118
Corn, dent, well-matured, well-eared ..	0.09	0.07	0.37	0.27	55	78	64	74	51
Corn, dent, well-matured, fair in ears	0.09	0.06	0.34	0.34	53	73	66	69	45
Corn, dent, well-matured, few ears ..	0.09	0.05	0.35	0.37	50	65	71	61	7
Corn, dent, immature, before dough stage ..	0.11	0.07	0.29	..	52	73	67	66	41
Corn, dent, immature, southern-type corn ..	..	..	0.26	..	53	73	66	62	15
Corn, dent, drouth-stricken corn	..	..	0.42	..	..	..	..	..	..
Corn stover silage from mature dent corn, ears removed	0.08	0.1	0.26	0.39	39	59	59	65	12
Corn, flint	..	..	0.26	..	57	81	65	77	7
Corn ears, snapped, immature	..	..	0.64	..	54	80	34	80	4
Corn, sweet	..	..	0.37	..	66	78	73	64	4
Corn and sorghum ...	0.08	0.05	0.30	..	..	..	..	..	..
Corn and soybeans, mostly corn	0.15	0.07	0.40	0.29	..	..	..	..	..
Corn and soybeans, well-matured, 30% or more soybeans ...	0.20	0.08	0.51	0.29	63	83	62	77	8
Corn-canning factory waste, (husks, cobs, and waste ears)	..	..	0.32	..	56	87	70	71	1
Cowpea, wilted	0.48	0.10	0.72	0.88	57	63	52	73	4
Crotalaria intermedia ..	0.18	0.06	0.48	..	63	67	33	41	4
Darso	..	..	0.30	..	..	60	39	70	3
Durra	..	..	0.29	..	..	..	..	..	..
Fescue, tall	..	..	0.69	..	60	64	69	66	12
Feterita	0.11	0.08	0.42	..	..	..	..	..	..
Grass silage, considerable legumes	..	..	0.58	..	..	..	..	..	..
Grass silage, considerable legumes, wilted	..	..	0.83	..	55	53	68	61	57

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Silages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Grass silage, considerable legumes, wilted, grain added	33.8	3.2	20.6	5.4	5.1	1.3	8.6	16.6	2.2	3
Grass silage, some legumes, molasses added *	25.8	1.9	15.1	6.9	3.2	1.2	8.5	11.2	1.7	2
Grass silage, some legumes, wilted, molasses added	33.6	2.6	19.1	6.3	4.5	1.2	10.5	14.6	2.8	16
Grass silage, small proportion legumes *	27.6	1.9	15.6	7.2	3.2	1.1	9.7	11.1	2.5	43
Grass silage, small proportion legumes, wilted *	37.3	2.3	21.1	8.2	4.0	1.1	14.1	15.4	2.7	5
Grass silage, small proportion legumes, wilted slightly, molasses added *	29.0	1.7	16.6	8.8	3.0	0.9	8.9	14.2	2.0	40
Hegari *	33.4	1.0	18.7	17.7	1.9	0.7	6.8	21.0	3.0	5
Hegari stover *	29.1	0.3	15.3	50.0	0.9	0.6	7.9	16.3	3.4	2
Horse bean *	21.2	2.1	12.3	4.9	3.3	0.5	5.7	10.3	1.4	3
Johnson grass, molasses added *	32.7	0.9	17.7	18.7	2.1	0.7	10.3	16.0	3.6	3
Kafir	29.7	1.1	16.9	14.4	2.1	1.0	8.4	15.9	2.3	7
Kochia scoparia *	21.4	2.2	11.8	4.4	3.5	0.5	6.7	8.0	2.7	3
Lespedeza, annual *	30.2	1.8	15.1	7.4	4.3	0.8	9.5	13.8	1.8	6
Millet *	31.2	1.6	17.6	10.0	2.7	1.0	9.7	14.9	2.9	8
Millet, Japanese, and soybeans	21.0	1.6	12.4	6.8	2.8	1.0	7.2	7.2	2.8	9
Napier grass, immature	19.9	0.3	8.1	26.0	1.1	0.5	7.3	8.4	2.6	2
Napier grass, more mature *	26.8	0.3	11.6	37.7	1.1	0.6	11.4	11.8	1.9	7
Oats, molasses added	32.0	1.4	16.9	11.1	2.7	1.2	10.3	15.4	2.4	3
Orchard grass	30.0	2.0	19.8	8.9	3.3	1.2	10.2	13.2	2.1	3
Pea, field *	27.9	3.0	18.1	5.0	3.8	1.2	7.8	12.5	2.6	8
Pea and oat	28.4	2.0	17.5	7.8	3.3	1.0	9.0	12.4	2.7	31
Pea-vine, from canneries	24.5	1.9	14.0	6.4	3.2	0.8	7.3	11.0	2.2	17
Pear-cannery waste and hay	27.6	1.7	14.6	7.6	3.3	0.9	9.0	12.2	2.2	2
Pineapple top *	21.3	0.5	8.9	16.8	1.6	0.6	4.8	12.8	1.5	1
Potato-alfalfa hay *	35.9	3.3	21.1	5.4	5.3	0.6	8.6	19.2	2.2	1
Potato-mixed hay *	33.7	2.2	21.6	8.8	3.8	0.8	6.0	21.1	2.0	4
Potato-corn meal	31.7	1.0	27.0	26.0	2.0	0.3	0.9	27.5	1.0	1
Reed canary grass *	26.7	1.4	13.3	8.5	2.2	0.7	8.4	13.4	2.0	2
Russian thistle *	34.4	1.3	14.3	10.0	2.0	0.9	10.4	14.7	6.4	1
Rye, wilted slightly *	30.3	1.5	14.5	8.7	3.5	1.0	10.8	12.5	2.5	7
Rye, molasses added *	23.7	1.0	11.4	10.4	2.4	0.7	8.4	10.4	1.8	1
Sagrain sorghum, well matured *	38.1	1.5	22.1	13.7	2.8	1.2	9.1	22.7	2.3	4
Sorghum, sweet	25.4	0.8	15.2	18.0	1.6	0.8	6.9	14.5	1.6	112

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents: Calcium	Phosphorus	Nitrogen	Potassium	Digestion coefficients: Protein	Fat	Fiber	N-free extract	No. of trials
Silages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Grass silage, considerable legumes, wilted, grain added	0.25	0.12	0.82	..	62	74	48	67	9
Grass silage, some legumes, molasses added	0.32	0.12	0.51	..	..	..	..	..	..
Grass silage, some legumes, wilted, molasses added	..	..	0.72	..	58	66	55	61	6
Grass silage, small proportion legumes	..	..	0.51	..	..	..	..	..	..
Grass silage, small proportion legumes, wilted	0.32	0.08	0.64	..	..	..	..	..	..
Grass silage, small proportion legumes, wilted slightly, molasses added	..	0.07	0.48	..	..	..	..	..	..
Hegari	..	..	0.30	..	..	..	..	..	..
Hegari stover	..	..	0.14	..	..	..	..	..	..
Horse bean	0.19	0.06	0.53	0.44	..	..	..	..	..
Johnson grass, molasses added	..	..	0.34	..	..	..	..	..	..
Kafir	0.07	0.05	0.34	0.50	..	50	57	62	3
Kochia scoparia	..	..	0.56	..	..	..	..	..	..
Lespedeza, annual	..	..	0.69	..	..	..	..	..	..
Millet	0.14	0.08	0.43	..	..	..	..	..	..
Millet, Japanese, and soybeans	..	..	0.45	..	57	72	69	59	4
Napier grass, immature	..	..	0.18	..	29	65	50	40	3
Napier grass, more mature	..	..	0.18	..	..	..	..	..	..
Oats, molasses added	0.10	0.09	0.43	0.30	53	66	48	57	12
Orchard grass	..	..	0.53	..	60	62	75	64	12
Pea, field	0.38	0.08	0.61	0.39	..	..	..	..	..
Pea and oat	0.17	0.09	0.53	..	61	66	65	66	30
Pea-vine, from canneries	0.32	0.06	0.51	..	59	57	50	68	12
Pear-cannery waste and hay	..	..	0.53	..	52	51	57	55	6
Pineapple top	..	..	0.26	..	..	..	..	..	..
Potato-alfalfa hay	..	..	0.85	..	..	..	..	..	..
Potato-mixed hay	..	..	0.61	..	..	..	..	..	..
Potato-corn meal	..	..	0.32	..	52	81	8	92	3
Reed canary grass	..	..	0.35	..	..	..	..	..	..
Russian thistle	..	..	0.32	..	..	..	..	..	..
Rye, wilted slightly	..	0.07	0.56	0.56	..	..	..	..	..
Rye, molasses added	..	..	0.38	..	..	..	..	..	..
Sagrain sorghum, well matured	..	..	0.45	..	..	..	..	..	..
Sorghum, sweet	0.08	0.05	0.26	0.26	..	58	57	65	5

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Silages—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Sorghum, Ellis *	32.2	1.4	19.0	12.6	2.7	0.9	7.6	18.6	2.4	2
Sorghum and cowpeas	32.3	1.3	18.4	13.2	2.4	1.0	8.5	18.2	2.2	8
Soybean, not wilted	24.8	2.9	14.6	4.0	4.2	0.7	7.3	10.0	2.6	34
Soybean, wilted	33.7	3.7	18.5	4.0	5.7	0.9	10.0	13.7	3.4	14
Soybean and Sud. grass *	24.5	2.4	14.0	4.8	3.4	0.5	8.5	10.0	2.1	1
Sudan grass	25.7	1.5	14.4	8.6	2.2	0.7	8.8	12.0	2.0	7
Sugar cane *	21.9	0.5	13.3	25.6	0.9	0.6	8.6	10.9	0.9	5
Sugar cane tops	29.6	0.8	15.5	18.4	1.5	0.6	10.6	14.1	2.8	3
Sunflower	22.6	1.0	12.2	11.2	2.1	1.0	7.0	10.2	2.3	93
Timothy, no preservative	30.9	1.8	18.4	9.2	3.3	1.1	11.0	13.3	2.2	8
Timothy, molasses added	30.0	1.6	17.1	9.7	3.1	1.0	10.2	13.6	2.1	1[illegible]
Timothy, grain added	33.1	2.3	19.2	7.3	4.0	1.1	10.4	15.6	2.0	3
Timothy, phosphoric acid added *	30.7	1.4	18.0	11.9	2.5	0.8	11.8	13.2	2.4	3
Timothy, wilted	40.8	2.2	23.5	9.7	4.4	1.3	14.2	18.0	2.9	13
Timothy, wilted, molasses added	42.5	2.1	25.5	11.1	4.1	1.3	14.2	20.1	2.8	27
Timothy, wilted, phosphoric acid added	36.6	1.4	20.1	13.4	3.2	1.1	12.6	17.1	2.6	10
Vetch	30.1	2.0	18.8	8.4	3.5	1.0	9.8	13.4	2.4	6
Vetch and oats	26.4	1.5	15.4	9.3	2.2	0.6	8.8	12.9	1.9	2
Vetch and wheat, molasses added *	29.2	1.9	17.5	8.2	2.9	1.0	7.9	15.2	2.2	5
Concentrates										
(Grains and other seeds and their by-products; miscellaneous concentrates)										
Acorns, whole (red oak) *	50.0	0	32.4	..	3.2	10.7	9.9	25.0	1.2	1
Acorns, whole (white and post oak)	50.0	0	23.4	..	2.7	3.0	9.3	33.7	1.3	6
Adlay, or Job's tears *	89.2	9.8	67.3	5.9	13.6	6.1	8.4	58.5	2.6	1
Alfalfa-molasses feed *	87.8	6.3	51.2	7.1	1.8	1.1	21.9	44.2	8.8	85
Alfalfa seed	88.3	27.9	81.3	1.9	33.2	10.6	8.1	32.0	4.4	1
Alfalfa seed screenings *	90.3	25.5	78.5	2.1	31.1	9.9	11.1	33.1	5.1	11
Almond hulls	88.4	0.4	66.2	164.5	3.8	3.6	9.7	65.4	5.9	73
Ammoniated cane molas., 16% protein equiv.*	70.2	12.3	53.6	3.4	16.4	0	0	47.5	6.3	3
Ammoniated cane molas., high protein equiv.*	63.9	23.9	46.5	0.9	31.9	0	0	26.0	6.0	2
Ammoniated citrus molasses *	60.8	13.2	46.5	2.5	17.6	2.2	0	37.1	3.9	1
Ammoniated citrus pulp, dried *	88.0	6.4	76.2	10.9	10.7	6.0	12.4	54.6	4.3	1
Ammoniated furfural residue *	94.3	26.2	42.6	0.6	34.9	0.4	51.7	2.4	4.9	1
Apple-pectin pulp, dr.*	91.2	2.6	62.4	23.0	7.0	7.3	24.2	49.4	3.3	6

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phos-phorus	Nitro-gen	Potas-sium	Protein	Fat	Fiber	N-free extract	No. of trials
Silages—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Sorghum, Ellis	..	..	0.43	..	..	..	..	..	..
Sorghum and cowpeas	0.14	0.04	0.38	0.30	..	49	64	58	2
Soybean, not wilted	0.35	0.09	0.67	0.23	70	63	46	73	13
Soybean, wilted	0.47	0.12	0.91	0.31	65	46	44	69	17
Soybean and Sudan grass	..	..	0.54	..	..	..	..	..	..
Sudan grass	0.11	0.04	0.35	..	69	71	67	49	3 †
Sugar cane	..	..	0.14	..	..	..	..	..	..
Sugar cane tops	..	..	0.24	..	54	53	60	54	16
Sunflower	0.39	0.04	0.34	0.66	49	69	44	64	46
Timothy, no preservative	0.18	0.09	0.53	0.52	55	58	66	59	6
Timothy, molasses added	0.16	0.08	0.50	..	50	60	59	60	20
Timothy, grain added	0.19	0.11	0.64	..	58	71	48	65	9
Timothy, phosphoric acid added	..	..	0.40	..	..	..	..	..	..
Timothy, wilted	0.23	0.12	0.70	0.69	50	58	62	60	10
Timothy, wilted, molasses added	0.22	0.16	0.66	..	51	59	65	62	20
Timothy, wilted, phosphoric acid added	..	..	0.51	..	44	60	59	57	8
Vetch	..	..	0.56	..	56	77	63	67	4 †
Vetch and oats	..	..	0.35	..	66	76	54	63	4 †
Vetch and wheat, molasses added	..	..	0.46	..	..	..	..	..	..
Concentrates									
(*Grains and other seeds and their by-products; miscellaneous concentrates*)									
Acorns, whole (red oak)	..	..	0.51	..	..	..	..	..	..
Acorns, whole (white and post oak)	..	..	.43	..	0	77	11	51	2
Adlay, or Job's tears	..	..	2.18	..	..	..	..	..	..
Alfalfa-molasses feed	..	..	1.89	..	..	..	..	..	..
Alfalfa seed	..	..	5.31	..	84	86	62	87	2
Alfalfa seed screenings	..	..	4.98	..	..	..	..	..	..
Almond hulls	..	..	0.61	..	1	65	54	84	6
Ammoniated cane molasses, 16% protein equiv.	..	..	2.62	..	..	..	..	..	..
Ammoniated cane molasses, high protein equiv.	..	..	5.10	..	..	..	..	..	..
Ammoniated citrus molasses	..	..	2.82	..	..	..	..	..	..
Ammoniated citrus pulp, dried	..	..	1.71	..	..	..	..	..	..
Ammoniated furfural residue	0.16	0.08	5.58	..	..	..	..	..	..
Apple-pectin pulp, dried	..	..	1.12	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Apple-pectin pulp, wet *	**16.7**	**0.6**	**11.1**	17.5	1.5	0.9	5.8	7.9	0.6	4
Apple pomace, dried ..	**89.6**	**1.6**	**64.5**	39.3	4.3	4.6	15.2	63.5	2.0	8
Apple pomace, wet ...	**21.1**	**0.5**	**16.0**	31.0	1.3	1.3	3.7	13.9	0.9	29
Atlas sorghum grain * .	**89.1**	**8.8**	**80.0**	8.1	11.3	3.3	2.0	70.6	1.9	3
Atlas sorghum-head chops *	**88.0**	**6.0**	**65.3**	9.9	9.5	2.8	10.7	60.2	4.8	3
Avocado oil meal	**91.4**	**8.2**	**52.3**	5.4	18.6	1.1	17.6	36.0	18.1	..
Babassu oil meal	**92.8**	**20.8**	**81.6**	2.9	24.2	6.8	12.0	44.6	5.2	8
Bag cleanings *	**90.4**	**13.8**	**68.3**	3.9	19.1	4.6	3.9	53.8	9.0	5
Bakery waste, dried, high in fat *	**91.6**	**10.0**	**101.2**	9.1	10.9	13.7	0.7	64.7	1.6	3
Barley, common, not including Pacific Coast states	**89.4**	**10.0**	**77.7**	6.8	12.7	1.9	5.4	66.6	2.8	109
Barley, common, ground, feed grade *	**89.3**	**9.2**	**75.6**	7.2	11.8	1.9	6.2	66.2	3.2	[illegible]
Barley, Pacific Coast states *	**89.9**	**6.9**	**78.8**	10.4	8.7	1.9	5.7	71.0	2.6	83
Barley, light weight ...	**89.1**	**9.2**	**69.0**	6.5	12.1	2.1	7.4	64.3	3.2	28
Barley, hull-less, or bald *	**90.2**	**9.2**	**80.4**	7.7	11.6	2.0	2.4	72.1	2.1	6
Barley feed, high grade *	**90.3**	**10.8**	**73.2**	5.8	13.5	3.5	8.7	60.5	4.1	39
Barley feed, low grade	**92.0**	**10.0**	**61.3**	5.1	12.3	3.5	14.7	56.2	5.3	19
Barley, malted *	**93.4**	**9.7**	**81.7**	7.4	12.7	2.1	5.4	70.9	2.3	6
Barley screenings * ...	**88.6**	**8.4**	**65.7**	6.8	11.6	2.7	9.1	61.3	3.9	5
Beans, field, or navy ..	**90.0**	**20.2**	**78.7**	2.9	22.9	1.4	4.2	57.3	4.2	27
Beans, kidney *	**89.0**	**20.2**	**77.8**	2.9	23.0	1.2	4.1	56.8	3.9	4
Beans, lima *	**89.5**	**18.5**	**77.6**	3.2	21.0	1.1	4.8	58.1	4.5	10
Beans, mung	**90.3**	**19.4**	**79.5**	3.1	23.6	1.2	3.3	58.2	4.0	10
Beans, pinto	**89.9**	**14.6**	**67.6**	3.6	22.5	1.2	4.1	57.7	4.4	7
Beans, tepary *	**90.5**	**14.4**	**68.6**	3.8	22.2	1.4	3.4	59.3	4.2	1
Beechnuts *	**91.4**	**12.2**	**84.9**	6.0	15.0	30.6	15.0	27.5	3.3	1
Beef scrap *	**94.5**	**45.6**	**69.6**	0.5	55.6	10.9	1.2	0.5	26.3	8
Beet pulp, dried	**91.2**	**4.1**	**68.7**	15.8	8.8	0.6	19.6	58.7	3.5	73
Beet pulp, molasses, dried	**92.2**	**5.9**	**72.4**	11.3	8.9	0.5	15.2	61.8	5.8	9
Beet pulp, wet	**11.6**	**0.8**	**8.8**	10.0	1.5	0.3	4.0	5.3	0.5	31
Beet pulp, wet, pressed *	**14.2**	**0.8**	**10.8**	12.5	1.4	0.4	4.6	7.1	0.7	10
Blood flour, or soluble blood meal	**92.2**	**81.3**	**83.9**	0.0	84.7	1.0	1.1	0.7	4.7	11
Blood meal	**91.6**	**58.4**	**60.4**	0.0	82.2	1.9	0.9	0.9	5.7	31
Bone meal, cooked	**93.6**	**17.9**	**18.6**	0.0	26.0	5.0	1.0	2.5	59.1	47
Bone meal, cooked, solvent *	**93.1**	**17.7**	**18.3**	0.0	25.7	1.0	1.0	1.9	63.5	50
Bone meal, steamed ..	**95.5**	..	..	..	7.5	1.2	1.5	3.2	82.1	36
Bone meal, steamed, solvent	**95.6**	..	..	..	5.5	0.4	1.4	3.3	85.0	31
Bone meal, 10 to 20% protein *	**94.3**	**9.0**	**10.2**	0.1	13.1	5.7	2.1	3.7	69.7	30
Bone meal, high protein, solvent *	**92.8**	**17.9**	**19.0**	0.1	25.9	2.5	1.8	3.8	58.8	34

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Apple-pectin pulp, wet	..	..	.24	..	..	..	..	..	..
Apple pomace, dried	0.10	0.09	.69	0.43	37	35	64	78	7
Apple pomace, wet	0.02	0.02	.21	0.10	..	46	65	85	6
Atlas sorghum grain	..	..	1.81	..	..	..	..	..	..
Atlas sorghum-head chops	..	..	1.52	..	..	..	..	..	..
Avocado oil meal	..	..	2.98	..	44	80	86	75	6
Babassu oil meal	0.13	0.71	3.87	..	86	90	72	86	6
Bag cleanings	..	..	3.06	..	..	..	..	..	..
Bakery waste, dried, high in fat	..	..	1.74	..	..	..	..	..	..
Barley, common, not including Pacific Coast states	0.06	0.40	2.03	0.49	79	80	56	92	16
Barley, common, ground, feed grade	..	..	1.89	..	..	..	..	..	..
Barley, Pacific Coast states	0.06	0.33	1.39	..	..	..	..	..	..
Barley, light weight	..	..	1.94	..	76	77	38	83	4
Barley, hull-less, or bald	..	..	1.86	..	..	..	..	..	..
Barley feed, high grade	0.03	0.40	2.16	0.60	..	..	..	..	..
Barley feed, low grade	..	..	1.97	..	81	90	18	74	4 †
Barley, malted	0.06	0.42	2.03	0.37	..	..	..	..	..
Barley screenings	..	..	1.86	..	..	..	..	..	..
Beans, field, or navy	0.15	0.57	3.66	1.27	88	85	74	92	34 †
Beans, kidney	..	..	3.68	..	..	..	..	..	..
Beans, lima	0.09	0.37	3.36	1.70	..	..	..	..	..
Beans, mung	0.14	0.35	3.78	..	82	100	100	93	12
Beans, pinto	0.13	0.46	3.60	..	65	44	52	86	6
Beans, tepary	..	..	3.55	..	..	..	..	..	..
Beechnuts	0.58	0.30	2.40	0.62	..	..	..	..	..
Beef scrap	..	..	8.90	..	..	..	..	..	..
Beet pulp, dried	0.69	0.08	1.41	0.18	47	0	75	85	9 †
Beet pulp, molasses, dried	0.57	0.07	1.42	1.63	66	0	80	88	9 †
Beet pulp, wet	0.09	0.01	.24	0.02	55	0	82	88	6 †
Beet pulp, wet, pressed	..	..	.22	..	..	..	..	..	..
Blood flour, or soluble blood meal	0.64	0.48	13.55	..	96	100	..	..	1 †
Blood meal	0.32	0.25	13.15	0.09	71	38	18	25	17 †
Bone meal, cooked	22.96	10.25	4.16	..	69	0	..	..	8 †
Bone meal, cooked, solvent	24.02	10.65	4.11	..	..	..	..	..	..
Bone meal, steamed	30.14	14.53	1.20	..	..	..	..	..	..
Bone meal, steamed, solvent	32.11	14.23	.88	..	..	..	..	..	..
Bone meal, 10 to 20% protein	26.77	12.32	2.10	..	..	..	..	..	..
Bone meal, high protein, solvent	22.20	9.65	4.14	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Bread, white, enriched *	64.1	7.8	63.4	7.1	8.5	2.0	0.3	52.0	1.3	..
Brewers' grains, dried, 25% protein or more	93.0	22.0	67.1	2.1	27.5	6.5	14.2	41.1	3.7	159
Brewers' grains, dried, below 25% protein	92.8	16.8	61.9	2.7	23.3	6.2	15.6	43.7	4.0	67
Brewers' grains, dried, from California barley *	91.1	15.6	60.8	2.9	20.0	5.7	18.1	43.6	3.7	4
Brewers' grains, dried, with molasses *	93.2	15.7	60.8	2.9	20.1	5.5	12.0	48.7	6.9	8
Brewers' grains, wet	23.7	4.2	16.1	2.8	5.7	1.6	3.6	11.8	1.0	53
Broom corn seed	89.7	4.5	63.6	13.1	9.4	3.7	5.6	68.1	2.9	6
Buckwheat, ordinary varieties	88.0	7.4	62.2	7.4	10.3	2.3	10.7	62.8	1.9	74
Buckwheat, Tartary *	88.1	7.3	61.8	7.5	10.1	2.4	12.7	60.9	2.0	[illegible]
Buckwheat feed, good grade *	89.3	11.7	52.5	3.5	18.5	4.9	18.2	43.5	4.2	29
Buckwheat feed, low grade *	88.3	5.2	32.8	5.3	13.3	3.4	28.6	39.8	3.2	31
Buckwheat flour *	88.1	8.9	76.2	7.6	10.2	2.1	0.9	73.4	1.5	11
Buckwheat kernels, without hulls *	88.0	12.3	76.4	5.2	14.1	3.4	1.8	66.5	2.2	40
Buckwheat middlings	88.7	25.8	75.7	1.9	29.7	7.3	7.4	39.4	4.9	25
Buttermilk *	9.4	3.3	9.1	1.8	3.5	0.6	0	4.5	0.8	..
Buttermilk, condensed *	29.5	9.7	26.4	1.7	10.8	2.2	0	12.6	3.9	21
Buttermilk, dried	92.0	28.6	83.1	1.9	31.8	6.1	0.5	43.6	10.0	54
Carob beans and pods	87.8	1.9	69.4	35.5	5.5	2.6	8.7	68.5	2.5	6
Carob bean pods	89.5	0.8	65.0	80.3	4.7	2.5	8.7	70.9	2.7	17
Carob bean seeds	88.5	8.7	71.1	7.2	16.7	2.6	7.6	58.4	3.2	5
Cassava roots, dried *	94.4	0.1	75.0	749.0	2.8	0.5	5.0	84.1	2.0	6
Cassava meal (starch waste) *	86.8	0	70.4	..	0.9	0.7	4.6	78.8	1.8	2
Cheese rind, or cheese meal *	91.0	53.6	83.2	0.6	59.5	8.9	0.4	10.7	11.5	..
Chess, or cheat, seed *	89.6	7.6	67.8	7.9	9.7	1.7	8.2	66.4	3.6	2
Chick peas *	90.0	17.5	78.1	3.5	20.3	4.3	8.5	54.0	2.9	..
Citrus meal, dried *	91.5	2.7	75.9	27.1	6.3	3.2	13.1	62.6	6.3	2
Citrus pulp, dried *	90.0	2.7	74.9	26.7	6.2	3.4	11.6	62.5	6.3	53
Citrus pulp and citrus molasses, dried *	89.0	2.6	73.3	27.2	6.1	2.8	9.7	63.4	7.0	4
Citrus pulp and molasses, dried *	91.5	2.7	77.2	27.6	6.3	4.4	11.0	63.8	6.0	8
Citrus pulp, fresh *	18.3	0.5	15.1	29.2	1.2	0.6	2.3	12.8	1.4	..
Citrus seed meal *	88.5	23.0	75.1	2.3	27.1	13.8	10.5	31.7	5.4	1
Clover seed, red	87.5	27.4	77.0	1.8	32.6	7.8	9.2	31.2	6.7	1
Clover seed, sweet *	92.2	30.3	64.9	1.1	37.4	4.2	11.3	35.8	3.5	1
Clover seed screenings, red *	90.5	23.1	70.3	2.0	28.2	5.9	10.2	40.3	5.9	1
Clover seed screenings, sweet *	90.1	17.8	64.7	2.6	21.7	3.7	14.7	41.1	8.9	28
Cocoa meal	96.0	9.0	60.7	5.7	24.3	17.1	5.1	43.7	5.8	17

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Bread, white, enriched .	0.06	0.10	1.36	0.10	..	..	..	..	..
Brewers' grains, dried, 25% protein or more	0.29	0.48	4.40	0.10	80	90	54	59	5 †
Brewers' grains, dried, below 25% protein .	..	..	3.73	..	72	85	45	60	15 †
Brewers' grains, dried, from California barley	..	..	3.20	..	..	..	..	..	..
Brewers' grains, dried, with molasses	..	..	3.22	..	..	..	..	..	..
Brewers' grains, wet ...	0.07	0.12	.91	0.02	73	84	39	64	2 †
Broom corn seed	0.48	0.35	1.50	..	48	78	28	75	18 †
Buckwheat, ordinary varieties	0.09	0.31	1.65	0.45	72	80	45	73	4 †
Buckwheat, Tartary ..	0.13	0.31	1.62	0.44	..	..	..	..	..
Buckwheat feed, good grade	..	0.48	2.96	0.66	..	..	..	..	..
Buckwheat feed, low grade	..	0.37	2.13	0.68	..	..	..	..	..
Buckwheat flour	0.01	0.09	1.63	0.16	..	..	..	..	..
Buckwheat kernels, without hulls	0.05	0.45	2.26	0.49	..	..	..	..	..
Buckwheat middlings .	..	1.02	4.75	0.98	87	83	32	86	5
Buttermilk	0.14	0.08	.56	0.07	..	..	..	..	..
Buttermilk, condensed .	0.44	0.26	1.73	0.23	..	..	..	..	..
Buttermilk, dried	1.40	0.98	5.09	0.71	90	98	1	94	2 †
Carob beans and pods	..	..	.88	..	34	56	61	86	4
Carob bean pods	..	..	.75	..	17	66	52	79	6 †
Carob bean seeds	..	..	2.67	..	52	68	77	90	8 †
Cassava roots, dried ...	..	..	.45	..	..	..	..	..	..
Cassava meal (starch waste)	..	0.03	.14	0.23	..	..	..	..	..
Cheese rind, or cheese meal	..	..	9.52	..	..	..	..	..	..
Chess, or cheat, seed ..	..	..	1.55	..	..	..	..	..	..
Chick peas	..	..	3.25	..	..	..	..	..	..
Citrus meal, dried	1.98	0.10	1.01	..	..	..	..	..	..
Citrus pulp, dried	2.04	0.15	.99	..	..	..	..	..	..
Citrus pulp and citrus molasses, dried	1.64	0.11	.98	..	..	..	..	..	..
Citrus pulp and molasses, dried	..	..	1.01	..	..	..	..	..	..
Citrus pulp, fresh	..	..	.19	..	..	..	..	..	..
Citrus seed meal	1.00	0.64	4.34	..	..	..	..	..	..
Clover seed, red	..	..	5.22	..	84	87	82	86	2
Clover seed, sweet	..	..	5.98	..	..	..	..	..	..
Clover seed screenings, red..............	..	..	4.51	..	..	..	..	..	..
Clover seed screenings, sweet	..	..	3.47	..	..	..	..	..	..
Cocoa meal	..	..	3.89	..	37	89	..	40	5

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cocoa shells	95.1	4.2	47.0	10.2	15.4	3.0	16.5	49.9	10.3	21
Coconut oil meal, exp. or hydr. process	93.0	18.0	77.1	3.3	21.2	6.7	11.2	47.4	6.5	35
Coconut oil meal, solvent process *	91.1	18.2	68.6	2.8	21.4	2.4	13.3	47.4	6.6	7
Coconut oil meal and molasses (candied copra) *	85.7	10.2	65.7	5.4	12.8	2.5	6.1	57.4	6.9	5
Coconut oil meal, high in fat *	93.1	16.3	83.7	4.1	20.4	12.0	11.3	42.9	6.5	10
Cod-liver oil meal *	92.5	41.3	108.7	1.6	50.4	28.9	0.7	9.6	2.9	6
Corn, dent, from National Research Council Nation-wide survey, good corn year										
Corn, dent, Grade No. 1	87.0	6.9	81.9	10.9	8.9	4.0	2.0	70.8	1.3	..
Corn, dent, Grade No. 2	85.0	6.7	80.1	11.0	8.7	3.9	2.0	69.2	1.2	169
Corn, dent, Grade No. 3 *	83.5	6.5	78.6	11.1	8.5	3.8	2.0	68.0	1.2	..
Corn, dent, from National Research Council Nation-wide survey, in year with much soft corn										
Corn, dent, Grade No. 2	85.0	7.0	80.0	10.4	9.1	3.9	2.1	68.7	1.3	189
Corn, dent, Grade No. 3 *	83.5	6.9	78.5	10.4	8.9	3.8	2.0	67.5	1.3	..
Corn, dent, Grade No. 4 *	81.1	6.7	76.2	10.4	8.7	3.7	2.0	65.5	1.2	..
Corn, dent, Grade No. 5 *	78.5	6.5	73.9	10.5	8.4	3.6	1.9	63.5	1.2	..
Corn, dent, recent feed control and experiment station analyses *	88.2	6.9	82.5	11.0	9.0	3.8	2.4	71.5	1.5	167
Corn, dent, soft or immature *	66.1	5.4	60.6	10.2	7.0	2.2	2.3	53.2	1.4	5
Corn, dent, soft, artificially dried *	86.4	6.9	79.5	10.5	9.0	2.8	2.4	70.5	1.7	2
Corn, flint *	88.5	7.5	83.4	10.1	9.8	4.3	1.9	71.0	1.5	451
Corn, pop *	90.0	8.9	85.3	8.6	11.5	5.0	1.9	70.1	1.5	13
Corn, sweet, mature *	90.7	8.9	88.6	9.0	11.5	7.9	2.4	67.1	1.8	72
Corn ears, including kernels and cobs (corn-and-cob meal) *	86.1	5.4	73.2	12.6	7.4	3.2	8.0	66.2	1.3	..
Corn ears, soft, or immature *	61.1	3.4	49.2	13.5	5.6	1.8	7.5	45.1	1.1	5
Corn, snapped, or ear-corn chops, with husks*	89.3	4.8	69.1	13.4	7.8	3.0	10.5	65.3	2.7	443
Corn, snapped, very soft, or immature *	60.0	3.0	45.1	14.0	5.3	1.8	8.2	42.7	2.0	2
Corn bran	90.4	5.6	69.4	11.4	9.8	7.4	8.9	61.9	2.4	51
Corn, cracked, hulled *	87.6	6.4	81.0	11.7	8.3	2.1	1.2	74.9	1.1	6
Corn feed meal *	87.8	7.0	82.6	10.8	9.1	4.2	2.1	70.8	1.6	23

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cocoa shells	. .	0.59	2.46	2.16	27	90	26	65	8 †
Coconut oil meal, exp. or hydr. process	0.21	0.64	3.39	1.95	85	100	46	82	7
Coconut oil meal, solvent process	. .	. .	3.42	. .	. .	. .	. .	. .	. .
Coconut oil meal and molasses (candied copra)	. .	. .	2.05	. .	. .	. .	. .	. .	. .
Coconut oil meal, high in fat	. .	. .	3.26	. .	. .	. .	. .	. .	. .
Cod-liver oil meal	0.16	0.69	8.06	. .	. .	. .	. .	. .	. .
Corn, dent, from National Research Council Nation-wide survey, good corn year									
Corn, dent, Grade No. 1	0.02	0.28	1.42	0.29	77	90	57	93	. .
Corn, dent, Grade No. 2	0.02	0.27	1.39	0.29	77	90	57	93	. .
Corn, dent, Grade No. 3	0.02	0.27	1.36	0.28	. .	. .	. .	. .	. .
Corn, dent, from National Research Council Nation-wide survey, in year with much soft corn									
Corn, dent, Grade No. 2	0.02	0.26	1.46	0.28	. .	. .	. .	. .	. .
Corn, dent, Grade No. 3	0.02	0.26	1.42	0.28	. .	. .	. .	. .	. .
Corn, dent, Grade No. 4	0.02	0.25	1.39	0.27	. .	. .	. .	. .	. .
Corn, dent, Grade No. 5	0.02	0.24	1.34	0.26	. .	. .	. .	. .	. .
Corn, dent, recent feed control and experiment station analyses	0.03	0.27	1.44	0.43	. .	. .	. .	. .	. .
Corn, dent, soft, or immature	. .	0.24	1.12	0.26	. .	. .	. .	. .	. .
Corn, dent, soft, artificially dried	. .	. .	1.44	. .	. .	. .	. .	. .	. .
Corn, flint	. .	0.33	1.57	0.32	. .	. .	. .	. .	. .
Corn, pop	. .	0.29	1.84	. .	. .	. .	. .	. .	. .
Corn, sweet, mature . .	. .	. .	1.84	. .	. .	. .	. .	. .	. .
Corn ears, including kernels and cobs (corn-and-cob meal)	0.04	0.22	1.18	0.40	. .	. .	. .	. .	. .
Corn ears, soft, or immature	. .	. .	0.90	. .	. .	. .	. .	. .	. .
Corn, snapped, or ear-corn chops, with husks	. .	. .	1.25	. .	. .	. .	. .	. .	. .
Corn, snapped, very soft, or immature . . .	. .	. .	0.85	. .	. .	. .	. .	. .	. .
Corn bran	0.04	0.14	1.57	0.56	57	78	63	73	17 †
Corn, cracked, hulled . .	. .	. .	1.33	. .	. .	. .	. .	. .	. .
Corn feed meal	0.03	0.34	1.46	0.28	. .	. .	. .	. .	. .

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. pro-tein	Total dig. nutri-ents	Nutri-tive ratio	Average total composition: Pro-tein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn germ meal	93.0	14.9	76.1	4.1	19.8	7.8	8.9	53.2	3.3	14
Corn gluten feed, all analyses	90.3	21.3	74.1	2.5	24.8	2.5	7.2	48.1	7.7	104
Corn gluten feed, 25% protein guarantee	91.0	21.6	75.6	2.5	25.1	2.8	7.4	48.8	6.9	45
Corn gluten meal, all analyses	91.6	36.7	79.7	1.2	43.2	2.2	3.8	38.9	3.5	42
Corn gluten meal, 41% protein guarantee	91.3	36.2	78.7	1.2	42.6	2.3	4.3	37.8	4.3	22
Corn grits *	88.4	6.5	80.8	11.4	8.5	0.5	0.6	78.4	0.4	9
Corn meal, degerminated, yellow *	88.7	6.7	81.2	11.1	8.7	1.2	0.6	77.1	1.1	5
Corn meal, degerminated, white *	88.4	6.6	80.2	11.2	8.6	1.2	0.7	76.1	1.8	4
Corn oil meal, exp. or hydr.	91.6	16.1	76.9	3.8	22.4	7.8	10.2	48.8	[illegible]	55
Corn oil meal, solvent process *	91.0	15.7	69.6	3.4	21.8	1.5	11.4	53.6	2.7	8
Corn starch *	88.9	0.6	87.9	145.5	0.6	0.1	0.2	87.9	0.1	16
Corn-and-oat feed, good grade *	89.4	8.4	77.2	8.2	10.9	4.0	6.1	64.9	3.5	36
Corn-and-oat feed, low grade *	90.1	6.7	60.9	8.1	10.6	3.8	9.6	61.3	4.8	10
Cottonseed, whole	92.7	17.1	90.8	4.3	23.1	22.9	16.9	26.3	3.5	67
Cottonseed, immature, dried *	93.2	11.5	74.6	5.5	20.5	15.9	24.1	29.0	3.7	16
Cottonseed, whole-pressed, 28% protein guarantee	92.4	20.2	58.6	1.9	28.0	5.2	21.4	33.2	4.6	62
Cottonseed feed, below 36% protein	92.4	27.0	65.4	1.4	34.6	6.3	14.1	31.5	5.9	147
Cottonseed flour *	94.4	46.7	80.7	0.7	57.0	7.2	2.1	21.6	6.5	9
Cottonseed kernels, without hulls *	93.6	31.5	117.3	2.7	38.4	33.3	2.3	15.1	4.5	78
Cottonseed meal or cake, 45% protein or more	94.3	37.4	75.1	1.0	45.6	5.7	10.3	25.9	6.8	2
Cottonseed meal or cake, 43% protein grade, not including Texas analyses	92.8	35.9	72.6	1.0	43.3	5.1	11.0	27.4	6.0	2
Cottonseed meal or cake, 43% protein grade, Texas analyses	92.6	33.7	72.3	1.1	42.1	6.1	10.5	28.3	5.6	728
Cottonseed meal or cake, 43% protein grade, solvent process *	91.0	33.3	65.2	1.0	41.6	2.0	10.7	31.1	5.6	21
Cottonseed meal or cake, 41% protein grade, not including Texas analyses *	92.9	33.3	71.7	1.2	41.6	6.0	10.7	28.1	6.5	68

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents: Calcium	Phosphorus	Nitrogen	Potassium	Digestion coefficients: Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn germ meal	..	0.58	3.17	0.21	75	96	68	72	3
Corn gluten feed, all analyses	0.41	0.80	3.97	0.54	86	67	80	90	38
Corn gluten feed, 25% protein guarantee	..	..	4.02	..	..	..	..	..	..
Corn gluten meal, all analyses	0.14	0.41	6.91	0.02	85	93	58	93	16
Corn gluten meal, 41% protein guarantee	0.15	0.36	6.82	..	..	..	..	..	..
Corn grits	0.01	0.12	1.36	..	..	..	..	..	..
Corn meal, degerminated, yellow	0.01	0.14	1.39	..	..	..	..	..	..
Corn meal, degerminated, white	0.01	0.14	1.38	..	..	..	..	..	..
Corn oil meal, exp. or hydraulic	0.06	0.56	3.58	..	72	82	82	78	7
Corn oil meal, solvent process	0.03	0.50	3.49	..	..	..	..	..	..
Corn starch	..	..	0.10	..	..	..	..	..	..
Corn-and-oat feed, good grade	0.05	0.30	1.74	0.34	..	..	..	..	..
Corn-and-oat feed, low grade	..	..	1.70	..	..	..	..	..	..
Cottonseed, whole	0.14	0.68	3.70	1.11	74	92	64	59	4
Cottonseed, immature, dried	..	..	3.28	..	..	..	..	..	..
Cottonseed, whole-pressed, 28% protein guarantee	0.17	0.64	4.48	1.25	72	97	32	61	16 †
Cottonseed feed, below 36% protein	0.26	0.83	5.54	1.22	78	92	26	69	13 †
Cottonseed flour	..	..	9.12	..	..	..	..	..	..
Cottonseed kernels, without hulls	..	..	6.14	..	..	..	..	..	..
Cottonseed meal or cake, 45% protein or more	0.23	1.12	7.30	..	82	97	44	80	5 †
Cottonseed meal or cake, 43% protein grade, not including Texas analyses	0.23	1.07	6.93	1.45	83	97	43	76	20
Cottonseed meal or cake, 43% protein grade, Texas analyses	0.19	0.97	6.74	1.34	80	97	42	74	12
Cottonseed meal or cake, 43% protein grade, solvent process	0.21	..	6.66	..	..	..	..	..	..
Cottonseed meal or cake, 41% protein grade, not including Texas analyses	0.20	1.11	6.66	1.48	..	..	..	..	..

Table I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition					
					Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cottonseed meal or cake, 41% protein grade, Texas analyses *	92.2	32.2	69.1	1.1	40.8	5.7	11.2	28.9	5.6	2,923
Cottonseed meal, 41% protein grade, solvent process *	91.5	32.5	63.3	0.9	41.1	2.1	11.0	31.1	6.2	190
Cottonseed meal or cake, 38–40% protein grade*	92.6	31.3	68.2	1.2	39.6	5.2	10.9	30.6	6.3	25
Cottonseed meal or cake, 36% protein grade *	92.6	28.2	64.4	1.3	36.1	5.4	14.4	30.9	5.8	16
Cowpea seed	89.0	19.2	75.9	3.0	23.4	1.3	3.9	56.8	3.6	52
Crab meal *	92.1	23.1	27.2	0.2	31.6	2.1	10.3	7.2	40.9	23
Darso grain	90.0	7.4	82.6	10.2	10.1	3.1	1.9	73.5	1.4	27
Distillers dried corn grains, without solubles	94.4	19.1	84.0	3.4	26.1	8.9	12.8	44.2	2.4	18
Distillers dried corn grains, with solubles *	92.9	19.4	82.1	3.2	26.6	9.8	9.2	42.6	4.7	24
Distillers dried corn grains, with solubles, fungal amylase proc.*	94.5	18.7	88.5	3.7	25.6	13.3	6.0	45.3	4.3	2
Distillers dried rye grains	92.3	14.6	59.1	3.0	24.4	5.6	11.5	48.3	2.5	3
Distillers dried sorghum grains *	94.0	20.4	79.7	2.9	28.0	7.4	13.9	40.0	4.7	4
Distillers dried wheat grains *	93.7	21.0	78.4	2.7	28.7	6.1	13.0	42.2	3.7	24
Distillers dried corn solubles	92.4	22.5	80.0	2.6	28.5	9.6	4.4	42.5	7.4	15
Distillers dried solubles, kind not stated *	91.3	20.1	77.1	2.8	25.5	7.2	4.1	46.4	8.1	24
Distillers dried molasses solubles *	94.9	10.2	71.4	6.0	12.9	0.6	0.7	56.0	24.7	4
Distillery stillage, corn, whole *	7.9	1.7	6.7	2.9	2.3	0.6	0.7	4.0	0.3	3
Distillery stillage, rye, whole *	5.9	1.1	3.6	2.3	1.9	0.3	0.5	2.9	0.3	2
Distillery stillage, strained *	3.8	0.7	2.5	2.6	1.1	0.4	0.2	1.8	0.3	2
Durra grain *	89.8	8.0	81.0	9.1	10.3	3.5	1.6	72.4	2.0	7
Emmer grain	91.1	9.7	72.2	6.4	12.1	1.9	9.8	63.6	3.7	42
Feather meal *	94.6	61.2	63.8	0.04	87.4	2.9	0.6	0	3.7	20
Fermentation solubles, dried *	94.7	25.4	78.8	2.1	32.1	5.1	7.2	43.8	6.5	9
Feterita grain	89.4	9.5	79.8	7.4	12.2	3.2	2.2	70.1	1.7	22
Feterita head chops *	89.6	7.5	72.8	8.7	10.7	2.6	7.4	65.7	3.2	18
Fish-liver oil meal *	92.8	56.5	96.6	0.7	62.8	17.3	1.2	5.4	6.1	9
Fish meal, all analyses	92.0	53.6	70.8	0.3	60.9	6.9	0.9	5.0	18.3	154
Fish meal, herring	93.5	64.5	81.7	0.3	72.5	7.3	0.7	1.5	11.5	8
Fish meal, menhaden	93.5	50.3	71.1	0.4	62.1	8.3	0.7	4.2	18.2	30
Fish meal, red fish *	94.1	50.0	74.2	0.5	56.8	11.1	0.9	0.9	24.4	16
Fish meal, salmon *	92.8	48.1	71.2	0.5	59.4	9.8	0.3	4.3	19.0	2

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phos-phorus	Nitro-gen	Potas-sium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cottonseed meal or cake, 41% protein grade, Texas analyses	0.24	0.89	6.53	..	..	..	..	..	..
Cottonseed meal, 41% protein grade, solvent process	..	1.19	6.58	..	..	..	..	..	..
Cottonseed meal or cake, 38–40% protein grade	0.20	1.01	6.34	1.57	..	..	..	..	..
Cottonseed meal or cake, 36% protein grade ..	..	..	5.78	..	..	..	..	..	..
Cowpea seed	0.10	0.46	3.74	1.30	82	69	63	92	6 †
Crab meal	15.15	1.63	5.06	0.45	..	..	..	..	..
Darso grain	0.02	0.32	1.62	..	73	87	81	92	2
Distillers dried corn grains, without solubles	0.11	0.48	4.18	0.24	73	97	83	79	23
Distillers dried corn grains, with solubles	0.16	0.74	4.26	..	..	..	..	..	..
Distillers dried corn grains, with solubles, fungal amylase process	..	..	4.10	..	..	..	..	..	..
Distillers dried rye grains	0.13	0.43	3.90	0.04	60	72	56	60	6 †
Distillers dried sorghum grains	0.15	0.77	4.48	..	..	..	..	..	..
Distillers dried wheat grains	0.05	0.55	4.59	..	..	..	..	..	..
Distillers dried corn solubles	0.33	1.39	4.56	..	79	72	74	91	8
Distillers dried solubles, kind not stated	..	..	4.08	..	..	..	..	..	..
Distillers dried molasses solubles	..	..	2.06	..	..	..	..	..	..
Distillery stillage, corn, whole	0.006	0.05	0.37	..	..	..	..	..	..
Distillery stillage, rye, whole	..	..	0.30	..	..	..	..	..	..
Distillery stillage, strained	0.004	0.05	0.18	..	..	..	..	..	..
Durra grain	..	..	1.65	..	..	..	..	..	..
Emmer grain	..	0.33	1.94	0.47	80	87	29	88	12 †
Feather meal	..	..	13.98	..	..	..	..	..	..
Fermentation solubles, dried	..	..	5.14	..	..	..	..	..	..
Feterita grain	0.02	0.33	1.95	..	78	75	..	91	6
Feterita head chops ...	..	..	1.71	..	..	..	..	..	..
Fish-liver oil meal	..	..	10.05	..	..	..	..	..	..
Fish meal, all analyses	5.36	3.42	9.74	0.40	88	95	..	..	47
Fish meal, herring	2.97	2.08	11.60	..	89	100	..	..	16 †
Fish meal, menhaden ..	5.30	2.81	9.94	..	81	100	..	..	2 †
Fish meal, redfish	4.01	2.44	9.09	..	..	..	..	..	..
Fish meal, salmon	5.49	3.65	9.50	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Fish meal, sardine	**94.0**	**53.3**	**71.1**	0.3	65.0	6.8	1.2	5.3	15.7	10
Fish meal, tuna	**90.1**	**42.5**	**60.9**	0.4	58.2	7.9	0.7	3.4	19.9	2
Fish meal, white fish	**90.7**	**58.5**	**72.4**	0.2	62.9	6.8	0.2	0.3	20.5	25
Fish, soluble, dried *	**91.2**	**63.5**	**79.2**	0.2	71.3	8.5	0.6	0.[illegible]	10.0	2
Fish solubles, condensed	**50.1**	**27.0**	**42.1**	0.6	30.3	7.7	0.1	2.6	9.4	6
Flaxseed	**93.8**	**21.8**	**108.3**	4.0	24.0	35.9	6.3	24.0	3.6	12
Flaxseed screenings	**91.6**	**8.9**	**58.4**	5.6	15.9	10.2	13.3	44.9	7.3	18
Flaxseed screenings oil feed *	**91.9**	**13.7**	**54.5**	3.0	24.5	7.2	11.8	39.7	8.7	9
Garbage, hotel and restaurant *	**26.3**	**2.2**	**23.5**	9.7	4.3	5.9	0.7	14.0	1.4	..
Garbage, municipal *	**31.5**	**2.5**	**24.5**	8.8	5.0	4.8	2.1	16.1	3.5	..
Garbage, processed, high in fat	**95.9**	**6.3**	**85.5**	12.6	17.5	23.7	20.0	21.8	12.9	4
Garbage, processed, low in fat *	**92.3**	**8.3**	**57.9**	6.0	23.1	3.5	13.5	38.1	14.1	4
Grapefruit pulp, dried	**91.4**	**1.5**	**73.3**	47.9	6.1	1.4	12.7	65.4	5.8	2
Grapefruit pulp, fresh *	**16.2**	**0.4**	**13.9**	33.8	1.6	1.4	2.7	9.9	0.6	1
Grape pomace, dried	**91.0**	**1.5**	**24.2**	15.1	12.2	6.9	30.2	36.7	5.0	5
Hegari grain *	**89.7**	**7.5**	**80.5**	9.7	9.6	2.6	2.0	73.9	1.6	21
Hegari head chops	**89.6**	**7.0**	**69.6**	8.9	10.0	2.1	11.9	60.6	5.0	6
Hempseed oil meal	**92.0**	**25.1**	**43.2**	0.7	31.0	6.2	23.8	22.0	9.0	2
Hominy feed, 5% fat or more	**89.9**	**7.5**	**83.9**	10.2	10.6	6.5	4.7	65.4	2.7	91
Hominy feed, low in fat *	**89.4**	**7.2**	**81.7**	10.3	10.1	4.6	3.9	68.5	2.3	14
Horse beans *	**87.5**	**22.1**	**73.6**	2.3	25.7	1.4	8.2	48.8	3.4	5
Ivory nut meal, vegetable	**89.4**	**0.8**	**79.0**	97.8	4.7	0.9	7.2	75.[illegible]	1.1	4
Jack beans	**89.3**	**20.7**	**81.7**	2.9	24.7	3.2	8.2	50.4	2.8	5
Kafir grain	**89.8**	**8.9**	**81.6**	8.2	11.0	2.9	1.7	72.6	1.6	71
Kafir head chops	**89.2**	**6.3**	**68.0**	9.8	10.0	2.6	6.9	66.4	3.3	54
Kalo sorghum grain *	**89.2**	**9.2**	**80.3**	7.7	11.8	3.2	1.6	70.9	1.7	1
Kaoliang grain *	**89.9**	**8.2**	**81.7**	9.0	10.5	4.1	1.6	71.8	1.9	16
Kelp, dried *	**91.3**	**2.5**	**28.9**	10.6	6.5	0.5	6.5	42.6	35.2	20
Lambs' quarters seed *	**90.0**	**13.4**	**55.2**	3.1	20.6	4.5	15.1	40.2	9.6	3
Lespedeza seed, annual	**91.7**	**29.6**	**65.2**	1.2	36.6	7.6	9.6	32.8	5.1	8
Lespedeza seed, sericea *	**92.3**	**25.8**	**61.0**	1.4	33.5	4.2	13.5	37.3	3.8	3
Lemon pulp, dried	**92.8**	**2.9**	**72.7**	24.1	6.4	1.2	15.0	65.2	5.0	1
Linseed meal, exp. or hydr. process, all analyses	**91.1**	**30.6**	**75.5**	1.5	35.2	4.6	8.9	36.7	5.7	155
Linseed meal, exp. or hydr. process, 37% protein grade *	**91.7**	**32.6**	**78.0**	1.4	37.5	5.9	8.2	34.6	5.5	8
Linseed meal, exp. or hydr. process, 36% protein grade *	**92.4**	**31.5**	**75.6**	1.4	36.2	3.9	9.0	37.5	5.8	5
Linseed meal, solvent process, 36% protein grade	**91.0**	**30.7**	**70.3**	1.3	36.6	1.0	9.3	38.3	5.8	19

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Fish meal, sardine	4.41	2.57	10.40	..	82	99	..	..	2 †
Fish meal, tuna	4.80	3.10	9.31	..	73	94	..	..	8
Fish meal, white fish ..	6.76	3.69	10.06	..	93	90	..	..	12 †
Fish, soluble, dried ...	..	..	11.41	..	..	..	..	..	..
Fish solubles, condensed	0.17	0.82	4.85	..	89	80	..	..	4 †
Flaxseed	0.22	0.52	3.84	0.79	91	86	60	55	7
Flaxseed screenings ...	0.37	0.43	2.54	..	56	71	13	70	21 †
Flaxseed screenings oil feed	..	..	3.92	..	..	..	..	..	..
Garbage, hotel and restaurant	0.11	0.07	0.69	..	..	..	..	..	..
Garbage, municipal ..	..	..	0.80	..	..	..	..	..	..
Garbage, processed, high in fat	..	0.33	2.80	0.62	36	82	88	82	3
Garbage, processed, low in fat	..	..	3.70	..	..	..	..	..	..
Grapefruit pulp, dried .	..	..	0.98	..	25	79	72	92	4
Grapefruit pulp, fresh .	0.19	0.03	0.26	..	..	..	..	..	..
Grape pomace, dried ..	..	..	1.95	..	12	56	15	26	15 †
Hegari grain	0.18	0.30	1.54	..	..	..	..	..	..
Hegari head chops	..	..	1.60	..	..	..	..	..	..
Hempseed oil meal ...	0.25	0.43	4.96	..	81	80	5	26	7 †
Hominy feed, 5% fat or more	0.05	0.57	1.70	0.61	71	92	86	90	11
Hominy feed, low in fat .	..	0.48	1.62	..	..	..	..	..	..
Horse beans	0.13	0.54	4.11	1.16	..	..	..	..	..
Ivory nut meal, vegetable	..	..	0.75	..	18	49	86	94	8
Jack beans	..	..	3.95	..	84	75	75	98	3 †
Kafir grain	0.03	0.31	1.76	0.34	81	76	55	92	2
Kafir head chops	0.08	0.27	1.60	..	63	74	61	80	2
Kalo sorghum grain ...	..	..	1.89	..	..	..	..	..	..
Kaoliang grain	..	..	1.68	..	..	..	..	..	..
Kelp, dried	2.48	0.28	1.04	..	..	..	..	..	..
Lambs'-quarters seed .	..	..	3.30	..	..	..	..	..	..
Lespedeza seed, annual	..	..	5.86	..	81	49	37	72	14
Lespedeza seed, sericea	..	..	5.36	..	..	..	..	..	..
Lemon pulp, dried	..	..	1.02	..	46	27	60	92	4
Linseed meal, exp. or hydr. process, all analyses	0.37	0.86	5.63	1.24	87	92	59	82	9
Linseed meal, exp. or hydr. process, 37% protein grade	0.39	0.86	6.00	1.10	..	..	..	..	..
Linseed meal, exp. or hydr. process, 36% protein grade	..	0.86	5.79	..	..	..	..	..	..
Linseed meal, solvent process, 36% protein grade	..	..	5.86	..	84	89	74	80	12

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Linseed meal, exp. or hydr. process, 34% protein guar.	91.0	30.5	75.3	1.5	35.1	4.5	9.0	36.7	5.7	113
Linseed meal, exp. or hydr. process, 32% protein guar.*	91.2	30.0	75.7	1.5	34.5	4.8	9.1	37.1	5.7	29
Linseed meal and screenings oil feed (linseed feed)*	90.6	23.8	66.3	1.8	31.7	5.3	10.1	36.9	6.6	6
Liver and glandular meal*	93.2	54.9	90.2	0.6	66.9	15.6	2.1	2.9	5.7	6
Liver meal, animal*	92.4	54.3	90.8	0.7	66.2	16.3	1.4	2.0	6.5	27
Locust beans and pods, honey*	88.4	3.2	65.1	19.3	9.3	2.4	16.1	57.1	3.5	3
Lupine seed, sweet, yellow	88.9	35.4	76.9	1.2	39.8	4.9	14.0	25.7	4.5	2
Malt, barley*	90.6	11.3	80.1	6.1	14.3	1.6	1.8	70.6	2.3	11
Malt sprouts	92.6	20.3	70.9	2.5	26.4	1.4	14.1	44.5	6.2	66
Meat scrap, or dry-rendered tankage, 55% protein grade	94.2	45.0	66.7	0.5	54.9	9.4	2.5	2.5	24.9	77
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade*	93.7	40.8	65.3	0.6	49.7	10.6	2.2	3.1	28.1	726
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade, solvent extracted*	93.7	40.9	50.5	0.2	49.9	3.7	2.4	3.3	34.4	78
Meat and bone scrap, or dry-rendered tankage with bone, 48% protein grade*	93.2	39.9	64.3	0.6	48.7	10.7	1.6	2.3	29.9	101
Meat and bone scrap, or dry-rendered tankage with bone, 45% protein grade*	94.0	37.3	65.5	0.8	45.5	12.3	2.3	2.9	31.0	58
Mesquite beans and pods	94.0	11.7	71.6	5.1	13.0	2.8	26.3	47.4	4.5	8
Milk, cow's	12.8	3.3	16.3	3.9	3.5	3.7	0	4.9	0.7	..
Milk, ewe's*	19.2	6.2	26.2	3.2	6.5	6.9	0	4.9	0.9	..
Milk, goat's*	13.2	3.4	17.1	4.0	3.6	4.1	0	4.7	0.8	..
Milk, mare's*	9.4	1.9	10.1	4.3	2.0	1.1	0	5.9	0.4	..
Milk, sow's*	20.1	6.9	26.7	2.9	7.3	6.7	0	5.1	1.0	105
Milk albumen, or lactalbumin, commercial*	92.0	44.6	58.5	0.3	49.5	0.9	1.0	12.8	27.8	6
Milk, whole, dried*	96.8	22.3	118.7	4.3	24.8	26.2	0.2	40.2	5.4	4
Millet seed, fox tail varieties*	89.1	8.6	75.7	7.8	12.1	4.1	8.6	60.7	3.6	33

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Linseed meal, exp. or hydr. process, 34% protein guar.	0.41	0.85	5.62	1.14	..	..	..	..	..
Linseed meal, exp. or hydr. process, 32% protein guar.	0.32	0.88	5.52	1.40	..	..	..	..	..
Linseed meal and screenings oil feed (linseed feed)	0.43	0.65	5.07	..	..	..	..	..	..
Liver and glandular meal	..	..	10.70	..	..	..	..	..	..
Liver meal, animal	0.62	1.27	10.59	..	..	..	..	..	..
Locust beans and pods, honey	..	..	1.49	..	..	..	..	..	..
Lupine seed, sweet, yellow	0.23	0.39	6.37	0.81	89	84	83	80	13 †
Malt, barley	0.08	0.47	2.29	..	..	..	..	..	..
Malt sprouts	0.26	0.79	4.22	..	77	85	87	80	5
Meat scrap, or dry-rendered tankage, 55% protein grade	8.49	4.18	8.78	..	82	97	..	..	3 †
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade	10.67	5.27	7.95	..	..	..	..	..	..
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade, solvent extracted	..	..	7.98	..	..	..	..	..	..
Meat and bone scrap, or dry-rendered tankage with bone, 48% protein grade	13.46	6.59	7.79	..	..	..	..	..	..
Meat and bone scrap, or dry-rendered tankage with bone, 45% protein grade	..	..	7.28	..	..	..	..	..	..
Mesquite beans and pods	..	..	2.08	..	90	95	59	81	2
Milk, cow's	0.12	0.10	0.56	0.14	95	98	..	98	23
Milk, ewe's	0.21	0.12	1.04	0.19	..	..	..	..	..
Milk, goat's	0.13	0.11	0.58	0.18	..	..	..	..	..
Milk, mare's	0.08	0.05	0.32	0.08	..	..	..	..	..
Milk, sow's	..	..	1.17	..	..	..	..	..	..
Milk albumen, or lactalbumin, commercial	10.02	3.53	7.92	..	..	..	..	..	..
Milk, whole, dried	0.91	0.76	3.97	1.06	..	..	..	..	..
Millet seed, foxtail varieties	..	0.20	1.94	0.31	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Millet seed, hog, or proso	90.4	8.4	76.9	8.2	11.9	3.4	8.1	63.7	3.3	69
Millet seed, Japanese *	89.8	7.6	73.6	8.7	10.6	4.9	14.6	54.7	5.0	4
Milo grain	89.0	8.5	79.4	8.3	10.9	3.0	2.3	70.[illegible]	2.1	61
Milo head chops	89.6	7.0	74.3	9.6	9.2	2.5	7.0	74.6	6.3	12
Milo gluten feed *	88.9	21.1	74.3	2.5	24.5	3.4	6.5	47.7	6.8	22
Milo gluten meal *	90.1	36.1	82.8	1.3	42.5	4.3	3.3	38.5	1.5	15
Molasses, beet	80.5	4.4	60.8	12.8	8.4	0	0	62.0	10.1	14
Molasses, beet, Steffen's process *	78.7	4.1	60.6	13.8	7.8	0	0	62.1	8.8	4
Molasses, cane, or blackstrap	73.4	0	53.7	..	3.0	0	0	61.7	8.6	40
Molasses, cane, from cane grown on nitrogen-rich muck *	80.2	4.7	60.4	11.9	9.0	0	0	64.0	7.2	3
Molasses, citrus *	70.4	0	53.6	..	4.1	0.2	0	61.5	4.6	27
Molasses, pear *	76.4	0	60.8	..	1.2	0	0	69.9	5.3	1
Molasses, wood *	58.3	0	48.4	..	0.5	0	0	55.6	2.2	3
Mustard seed, wild yellow *	95.9	15.0	90.8	5.1	23.0	38.8	5.0	23.6	5.5	1
Mustard seed oil meal *	94.0	23.0	67.6	1.9	27.1	6.4	12.1	41.8	6.6	1
Oat clippings, or clipped oat by-product	92.2	3.5	51.0	13.6	8.8	2.3	25.3	44.9	10.9	5
Oat kernels, without hulls (oat groats) *	90.4	14.6	91.9	5.3	16.2	6.1	2.2	63.7	2.2	45
Oat meal, feeding, or rolled oats	90.8	14.5	91.4	5.3	16.1	5.5	2.6	64.2	2.4	66
Oat middlings	91.4	12.7	86.6	5.8	15.9	5.2	3.3	64.6	2.4	6
Oat mill by-product (oat mill feed), usual grade	93.6	2.7	36.8	12.6	4.1	1.1	31.5	51.0	5.9	10
Oat mill by-product, high grade *	91.5	7.9	58.8	6.4	10.8	3.9	17.7	53.2	5.9	10
Oat mill by-product, with molasses *	92.4	3.6	37.2	9.3	5.5	1.4	24.1	55.0	6.4	31
Oats, not including Pacific Coast states	90.2	9.4	70.1	6.5	12.0	4.6	11.0	58.6	4.0	498
Oats, Pacific Coast states *	91.2	7.0	72.2	9.3	9.0	5.4	11.0	62.1	3.7	118
Oats, ground, usual commercial feed grade *	89.8	9.0	68.5	6.6	11.6	4.1	12.1	57.7	4.3	419
Oats, light weight	91.2	8.3	59.8	6.2	12.0	4.5	15.1	54.9	4.7	32
Oats, wild	89.0	9.1	53.9	4.9	12.7	5.5	15.2	50.9	4.7	2
Olive pulp, dried, pits removed *	95.1	7.7	74.6	8.7	14.0	27.4	19.3	31.0	3.4	1
Olive pulp, dried, pits removed, solvent extracted *	91.3	7.2	32.3	3.5	13.0	3.6	24.6	41.6	8.5	1
Olive pulp, dried, with pits	92.0	0	36.5	..	5.9	15.6	36.5	31.5	2.5	1
Orange pulp, dried	87.9	6.1	78.4	11.9	7.7	1.5	8.0	67.3	3.4	3
Palm-kernel oil meal	91.4	15.4	76.5	4.0	19.2	6.7	11.9	49.7	3.9	6

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Millet seed, hog, or proso	0.05	0.30	1.90	0.43	71	73	53	92	6
Millet seed, Japanese	..	0.44	1.70	0.33	..	..	..	..	..
Milo grain	0.03	0.28	1.74	0.35	78	78	58	91	16
Milo head chops	0.14	0.26	1.47	..	76	87	52	91	4
Milo gluten feed	..	..	3.92	..	..	..	..	..	..
Milo gluten meal	..	..	6.80	..	..	..	..	..	..
Molasses, beet	0.05	0.02	1.34	4.77	52	..	..	91	4
Molasses, beet, Steffen's process	0.11	0.02	1.25	4.66	..	..	..	..	..
Molasses, cane, or blackstrap	0.66	0.08	0.48	3.67	0	..	..	87	30 †
Molasses, cane, from cane grown on nitrogen-rich muck	..	..	1.44	..	..	..	..	..	..
Molasses, citrus	1.08	0.08	0.66	..	..	..	..	..	..
Molasses, pear	..	..	0.19	..	..	..	..	..	..
Molasses, wood	1.48	0.02	0.08	..	..	..	..	..	..
Mustard seed, wild yellow	..	..	3.68	..	..	..	..	..	..
Mustard seed oil meal	..	..	4.34	..	..	..	..	..	..
Oat clippings, or clipped oat by-product	..	..	1.41	..	40	71	63	62	6
Oat kernels, without hulls (oat groats)	0.08	0.46	2.59	0.39	..	..	..	..	..
Oat meal, feeding, or rolled oats	0.07	0.46	2.58	0.37	90	96	80	98	2
Oat middlings	0.08	0.45	2.54	0.57	80	93	49	95	2
Oat mill by-product (oat mill feed), usual grade	0.18	0.20	0.66	0.60	66	74	36	41	32
Oat mill by-product, high grade	..	..	1.73	..	..	..	..	..	..
Oat mill by-product, with molasses	..	..	0.88	..	..	..	..	..	..
Oats, not including Pacific Coast states	0.09	0.33	1.92	0.43	78	88	38	81	19
Oats, Pacific Coast states	..	..	1.44	..	..	..	..	..	..
Oats, ground, usual commercial feed grade	..	..	1.86	..	..	..	..	..	..
Oats, light weight	..	..	1.92	..	69	86	36	68	9 †
Oats, wild	..	..	2.03	..	72	94	17	60	2
Olive pulp, dried, pits removed	..	..	2.24	..	..	..	..	..	..
Olive pulp, dried, pits removed, solvent extracted	..	..	2.08	..	..	..	..	..	..
Olive pulp, dried, with pits	..	..	0.94	..	0	86	0	20	5
Orange pulp, dried	..	..	1.23	..	79	49	84	95	5
Palm-kernel oil meal	..	0.69	3.07	0.42	80	76	54	87	13

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Palm seed, Royal *	86.5	3.7	64.3	16.4	6.1	8.3	22.8	43.8	5.5	1
Palmo middlings *	93.4	13.4	82.5	5.2	16.2	8.3	7.6	55.3	6.0	5
Pea feed, or pea meal	90.0	14.5	77.9	4.4	17.7	1.4	23.7	43.7	3.5	4
Pea hulls of seeds, or bran	91.5	3.4	69.7	19.5	4.8	0.4	48.5	3[illegible].3	3.5	4
Pea seed, field	90.7	20.1	77.9	2.9	23.4	1.2	6.1	57.0	3.0	15
Pea seed, field, cull *	91.6	18.9	79.1	3.2	22.0	1.1	5.9	59.8	2.8	3
Pea seed, garden *	89.2	21.8	76.9	2.5	25.3	1.7	5.7	53.6	2.9	12
Peanut kernels, without hulls *	94.6	27.7	137.9	4.0	30.4	47.7	2.5	11.7	2.3	113
Peanut oil meal, 50% protein grade, solvent *	93.0	47.6	77.3	0.6	52.3	1.6	6.9	26.3	5.9	1
Peanut oil meal, 45% protein grade, exp. or hydr., well hulled	94.0	42.4	84.5	1.0	46.6	6.3	5.5	30.2	5.4	17
Peanut oil meal and hulls, 45% protein grade, exp. or hydr.	93.4	40.3	76.0	0.9	45.3	6.8	12.6	23.7	5.0	52
Peanut oil meal and hulls, 45% protein grade, solvent *	93.0	41.9	68.5	0.6	47.1	1.5	14.9	25.0	4.5	2
Peanut oil meal and hulls, 43% protein grade, exp. or hydr. *	91.8	38.6	76.6	1.0	43.4	6.8	12.1	24.0	5.5	21
Peanut oil meal and hulls, 41% protein grade, exp. or hydr. *	92.3	36.6	73.3	1.0	41.1	6.6	15.0	24.8	4.8	247
Peanut oil meal and hulls, 41% protein grade, solvent *	91.8	38.0	66.2	0.6	42.7	1.9	17.0	25.4	4.8	4
Peanut skins	93.8	4.1	61.5	14.0	16.3	23.9	11.8	39.1	2.7	4
Peanut screenings *	90.6	9.7	40.8	3.2	13.8	8.8	23.8	37.3	6.9	15
Peanuts, with hulls	94.1	20.2	103.5	4.1	24.9	36.2	17.5	12.6	2.9	68
Pear-cannery waste, fresh *	15.2	0.2	11.0	54.0	0.6	0.2	2.6	11.5	0.3	2
Pear pomace, dried *	90.8	2.3	65.3	27.4	6.1	1.3	13.1	68.7	1.6	1
Pear pulp, dried *	92.4	2.0	61.3	29.7	5.4	2.9	31.5	47.2	5.4	1
Perilla oil meal	91.9	34.2	61.4	0.8	38.4	8.4	20.9	16.0	8.2	4
Pigeon-grass seed *	89.8	9.4	58.2	5.2	14.4	6.0	17.3	45.8	6.3	9
Pigweed seed *	90.0	10.9	61.4	4.6	16.8	6.2	15.9	47.8	3.3	1
Pineapple bran, or pulp, dried	88.6	0.8	63.8	78.8	4.2	1.6	18.4	61.8	2.6	2
Pineapple bran, or pulp, and molasses, dried	87.4	0.8	62.7	77.4	3.9	1.0	15.9	63.4	3.2	8
Poppy-seed oil meal	89.2	30.4	62.3	1.0	36.6	7.9	11.6	20.7	12.4	2
Potato meal, or dried potatoes	91.4	3.5	70.4	19.1	9.7	0.3	2.1	75.0	4.3	9
Potato pulp, dried, from starch manufacture	87.7	5.6	78.5	13.0	7.3	0.4	7.7	69.1	3.2	4
Potato pulp, dried, lime added *	88.0	2.8	72.5	24.9	3.6	0.3	10.4	64.2	9.5	6

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Palm seed, Royal	..	..	0.98	..	..	..	..	..	..
Palmo middlings	..	..	2.59	..	..	..	..	..	..
Pea feed, or pea meal	..	..	2.83	..	82	68	87	93	3
Pea hulls of seeds, or bran	0.98	0.08	0.77	..	71	75	78	81	9 †
Pea seed, field	0.17	0.50	3.74	1.03	86	64	50	93	6 †
Pea seed, field, cull	0.17	0.32	3.52	..	..	..	..	..	..
Pea seed, garden	0.08	0.40	4.05	0.90	..	..	..	..	..
Peanut kernels, without hulls	0.06	0.44	4.86	0.54	..	..	..	..	..
Peanut oil meal, 50% protein grade, solvent	..	..	8.37	..	..	..	..	..	..
Peanut oil meal, 45% protein grade, exp. or hydr., well hulled	0.16	0.54	7.46	1.15	91	92	51	87	20 †
Peanut oil meal and hulls, 45% protein grade, exp. or hydr.	..	..	7.25	..	..	..	..	..	..
Peanut oil meal and hulls, 45% protein grade, solvent	..	..	7.54	..	..	..	..	..	..
Peanut oil meal and hulls, 43% protein grade, exp. or hydr.	..	..	6.90	..	..	..	..	..	..
Peanut oil meal and hulls, 41% protein grade, exp. or hydr.	..	..	6.58	..	..	..	..	..	..
Peanut oil meal and hulls, 41% protein grade, solvent	..	..	6.83	..	..	..	..	..	..
Peanut skins	..	..	2.61	..	25	92	..	16	2
Peanut screenings	..	..	2.21	..	..	..	..	..	..
Peanuts, with hulls	..	0.33	3.98	0.53	81	93	34	13	4
Pear-cannery waste, fresh	..	..	0.10	..	..	..	..	..	..
Pear pomace, dried	..	..	0.98	..	..	..	..	..	..
Pear pulp, dried	2.20	0.11	0.86	..	..	..	..	..	..
Perilla oil meal	0.56	0.47	6.14	..	89	92	18	38	8 †
Pigeon-grass seed	..	..	2.30	..	..	..	..	..	..
Pigweed seed	..	..	2.69	..	..	..	..	..	..
Pineapple bran, or pulp, dried	0.28	0.08	0.67	..	20	61	75	76	4
Pineapple bran, or pulp, and molasses, dried	..	..	0.62	..	21	0	70	80	4
Poppy-seed oil meal	..	..	5.86	..	83	94	35	54	15 †
Potato meal, or dried potatoes	0.07	0.20	1.55	1.97	36	26	0	89	47 †
Potato pulp, dried, from starch manufacture	..	..	1.17	..	77	27	64	98	..
Potato pulp, dried, lime added	3.69	0.16	0.58	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. pro-tein	Total dig. nutri-ents	Nutri-tive ratio	Average total composition: Pro-tein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Poultry by-product meal	93.4	47.1	73.9	0.6	55.4	13.1	1.6	4.6	18.7	25
Pumpkin seed, not dried *	55.0	14.8	68.7	3.6	17.6	20.6	10.8	4.1	1.9	1
Raisin pulp, dried	89.4	2.3	47.5	19.7	9.6	7.8	16.1	50.6	5.3	4
Raisins, cull *	84.8	0.8	41.5	50.9	3.4	0.9	4.4	7[illegible].1	3.0	3
Rape seed *	90.5	17.3	117.1	5.8	20.4	43.6	6.6	15.7	4.2	2
Rape-seed oil meal	89.5	28.5	68.1	1.4	33.5	8.1	10.8	30.2	6.9	..
Rice, brewers' *	88.3	5.8	80.6	12.9	7.5	0.6	0.6	78.8	0.8	6
Rice, brown *	87.8	7.0	81.0	10.6	9.1	2.0	1.1	74.5	1.1	18
Rice, polished *	87.8	5.7	80.1	13.1	7.4	0.4	0.4	79.1	0.5	45
Rice bran	90.8	8.4	67.4	7.0	12.4	13.6	11.6	39.9	13.3	93
Rice bran, solvent extracted *	90.9	9.7	55.3	4.7	14.3	3.1	12.0	47.9	13.6	10
Rice bran, with added calcium carbonate *	90.1	7.7	67.0	7.7	11.3	13.6	11.6	40.3	13.3	98
Rice grain, or rough rice	88.8	6.0	70.2	10.7	7.9	1.8	9.0	64.9	5.2	18
Rice polishings, or rice polish	89.8	9.7	81.5	7.4	12.8	13.4	2.7	51.0	9.9	48
Rice polishings, with added calcium carbonate *	89.9	9.2	81.8	7.9	12.1	14.9	4.1	48.1	10.7	19
Rubber-seed oil meal	91.1	20.4	63.4	2.1	28.8	9.2	10.0	37.6	5.5	2
Rye grain	89.5	10.0	76.5	6.7	12.6	1.7	2.4	70.9	1.9	56
Rye feed	90.4	12.2	68.1	4.6	16.1	3.3	4.6	62.7	3.7	154
Rye flour *	88.6	8.5	74.5	7.8	11.2	1.3	0.6	74.6	0.9	..
Rye flour middlings	90.6	11.9	72.8	5.1	16.5	3.5	4.2	63.1	3.3	7
Rye middlings	90.2	12.6	72.0	4.7	16.6	3.4	5.2	61.2	3.8	81
Rye middlings and screenings *	90.4	12.7	71.6	4.6	16.7	3.8	6.1	59.5	4.3	79
Safflower seed *	93.1	13.0	82.4	5.3	16.3	29.8	26.6	17.5	2.9	1
Safflower-seed oil meal, from well hulled seed *	90.5	37.4	69.4	0.9	42.5	6.7	8.5	26.4	6.4	1
Safflower-seed oil meal, from unhulled seed	91.5	17.2	50.1	1.9	21.5	6.9	32.8	26.5	3.8	2
Safflower-seed oil meal, from partly hulled seed	94.0	30.3	65.1	1.1	34.4	6.2	18.4	28.8	6.2	2
Safflower-seed oil meal, from partly hulled seed, solvent *	93.8	19.2	52.6	1.7	21.8	1.0	26.9	40.1	4.0	1
Sagrain sorghum grain*	90.0	7.4	81.6	10.0	9.5	3.5	2.1	73.4	1.5	2
Screenings, grain, good grade	90.0	9.2	62.8	5.8	12.8	4.7	11.8	51.9	8.8	16
Screenings, grain, higher in fiber	90.4	8.5	56.5	5.6	13.1	5.4	16.1	46.1	9.7	24
Screenings, refuse	90.3	7.2	50.3	6.0	10.4	3.9	28.3	38.1	9.6	7
Schrock sorghum grain *	89.1	8.0	79.6	9.0	10.2	3.0	3.4	70.8	1.7	3
Sesame seed *	92.0	20.3	95.8	3.7	22.3	42.9	10.3	10.9	5.6	2
Sesame oil meal	93.7	39.4	71.3	0.8	43.3	9.0	6.2	23.6	11.6	7
Shallu grain *	89.8	10.5	80.7	6.7	13.4	3.7	1.9	68.9	1.9	19
Shallu head chops *	90.5	8.0	69.0	7.6	12.7	3.5	9.2	61.9	3.2	3

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Poultry by-product meal	..	..	8.86	..	..	..	..	..	..
Pumpkin seed, not dried	..	..	2.82	..	..	..	..	..	..
Raisin pulp, dried	..	..	1.54	..	24	90	19	52	5
Raisins, cull	..	..	0.54	..	..	..	..	..	..
Rape seed	..	..	3.26	..	..	..	..	..	..
Rape-seed oil meal	..	..	5.36	..	85	89	24	69	9 †
Rice, brewers'	0.04	0.10	1.20	..	..	..	..	..	..
Rice, brown	0.04	0.25	1.46	..	..	..	..	..	..
Rice, polished	0.01	0.09	1.18	0.04	..	..	..	..	..
Rice bran	0.08	1.36	1.98	1.74	68	83	28	76	22 †
Rice bran, solvent extracted	..	..	2.29	..	..	..	..	..	..
Rice bran, with added calcium carbonate	8.82	..	1.81	..	..	..	..	..	..
Rice grain, or rough rice	0.08	0.32	1.26	0.34	76	76	23	91	6
Rice polishings, or rice polish	0.05	1.18	2.05	1.17	76	86	34	88	12 †
Rice polishings, with added calcium carbonate	..	..	1.94	..	..	..	..	..	..
Rubber-seed oil meal	..	..	4.61	..	71	92	21	58	4
Rye grain	0.10	0.33	2.02	0.47	79	53	..	90	5 †
Rye feed	0.08	0.69	2.58	0.83	76	61	12	81	15 †
Rye flour	0.02	0.28	1.79	0.46	..	..	..	..	..
Rye flour middlings	..	..	2.64	..	72	86	11	85	2 †
Rye middlings	0.06	0.63	2.66	0.63	76	76	30	85	11 †
Rye middlings and screenings	..	..	2.67	..	..	..	..	..	..
Safflower seed	..	..	2.61	..	..	..	..	..	..
Safflower-seed oil meal, from well hulled seed	..	..	6.80	..	..	..	..	..	..
Safflower-seed oil meal, from unhulled seed	..	..	3.44	..	80	82	22	49	8
Safflower-seed oil meal, from partly hulled seed	..	..	5.50	..	88	89	23	63	16
Safflower-seed oil meal, from partly hulled seed, solvent	..	..	3.49	..	..	..	..	..	..
Sagrain sorghum grain	0.02	0.27	1.52	..	..	..	..	..	..
Screenings, grain, good grade	0.43	0.39	2.05	..	72	88	6	84	10 †
Screenings, grain, higher in fiber	..	..	2.10	..	65	64	18	81	2 †
Screenings, refuse	..	..	1.66	..	69	71	32	73	3
Schrock sorghum grain	..	..	1.63	..	..	..	..	..	..
Sesame seed	0.94	0.70	3.57	..	..	..	..	..	..
Sesame oil meal	2.02	1.61	6.93	1.35	91	65	55	65	16 †
Shallu grain	..	..	2.14	..	..	..	..	..	..
Shallu head chops	..	..	2.03	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Shark meal*	**91.2**	52.9	**55.2**	0.0	74.5	2.7	0.5	0	13.5	24
Shrimp meal*	**89.7**	37.8	**43.5**	0.2	46.7	2.8	11.1	1.3	27.8	18
Skimmilk, centrifugal*	**9.5**	3.4	**8.7**	1.6	3.6	0.1	0	5.1	0.7	..
Skimmilk, gravity	**10.1**	3.4	**10.2**	2.0	3.6	0.8	0	5.0	0.7	..
Skimmilk, dried	**93.9**	29.8	**79.8**	1.7	33.1	1.1	0.6	51.1	8.0	20
Sorghum grain, combine types*	**89.6**	8.4	**79.9**	8.5	10.8	2.8	2.3	71.7	2.0	50
Sorghum seed, Norghum	**88.4**	8.5	**79.6**	8.4	11.5	3.0	1.8	70.6	1.5	3
Sorghum seed, sweet	**89.2**	5.8	**77.5**	12.4	9.5	3.3	2.0	72.8	1.6	41
Sorghum gluten feed*	**90.7**	21.4	**75.6**	2.5	24.9	3.6	6.5	48.4	7.3	7
Sorghum gluten meal*	**90.0**	35.3	**83.2**	1.4	41.5	4.3	2.9	40.1	1.2	4
Soybean seed	**90.0**	33.7	**87.6**	1.6	37.9	18.0	5.0	24.5	4.6	452
Soybean flour, medium in fat*	**92.9**	40.2	**82.0**	1.0	47.9	6.7	2.4	29.9	6.0	4
Soybean flour, solvent extracted*	**91.5**	40.7	**74.2**	0.8	48.5	0.8	2.6	33.0	6.6	4
Soybean mill feed, chiefly hulls*	**88.0**	7.9	**37.0**	3.7	12.0	1.2	35.8	34.5	4.5	..
Soybean oil meal, exp. or hydr., all analyses	**91.0**	37.0	**77.9**	1.1	44.0	4.9	5.9	30.0	6.2	490
Soybean oil meal, solvent, all analyses	**90.4**	42.0	**78.1**	0.9	45.7	1.3	5.9	31.4	6.1	219
Soybean oil meal, solvent, 44% protein guarantee*	**90.3**	42.0	**78.0**	0.9	45.7	1.3	5.8	31.4	6.1	206
Soybean oil meal, exp. or hydr., 43% protein guarantee*	**91.4**	36.9	**78.6**	1.1	43.9	5.2	5.9	30.2	6.2	26
Soybean oil meal, exp. or hydr., 41% protein guarantee*	**90.9**	37.0	**77.7**	1.1	44.0	4.8	5.9	30.0	6.2	425
Soybean oil meal, exp. or hydr., 41% protein guarantee, with added calcium carbonate*	**91.0**	37.1	**77.0**	1.1	44.2	5.3	5.9	27.9	7.7	11
Soybean oil meal, dehulled, solvent, 50% protein guarantee*	**91.7**	46.4	**79.4**	0.7	50.4	1.0	3.2	31.0	6.1	6
Starfish meal*	**96.5**	24.8	**36.5**	0.5	30.6	5.8	1.9	14.3	43.9	3
Sudan-grass seed*	**92.4**	9.2	**47.1**	4.1	14.2	2.4	25.4	38.4	12.0	1
Sunflower seed*	**93.6**	13.9	**76.3**	4.5	16.8	25.9	29.0	18.8	3.1	15
Sunflower seed, hulled*	**95.5**	25.2	**116.1**	3.6	27.7	41.4	6.3	16.3	3.8	6
Sunflower-seed oil meal, from well-hulled seed	**94.3**	45.0	**70.8**	0.6	49.5	4.9	5.4	28.6	5.9	2
Sunflower-seed oil cake, from unhulled seed, solvent	**89.2**	16.3	**35.6**	1.2	19.6	1.1	35.9	27.0	5.6	..
Sweet potato meal, or dried sweet potatoes	**90.2**	0.7	**72.7**	102.9	4.9	0.9	3.3	77.0	4.1	50
Sweet potato pomace, dried, from starch manufacture*	**90.2**	0.4	**69.0**	171.5	2.5	0.3	9.6	71.8	6.0	1

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Shark meal	3.48	1.92	11.92	..	..	..	..	..	..
Shrimp meal	..	.	7.47	..	..	..	..	..	..
Skimmilk, centrifugal	0.13	0.10	0.58	0.15	..	..	..	..	..
Skimmilk, gravity	0.13	0.10	0.58	0.15	94	100	..	100	3
Skimmilk, dried	1.28	1.04	5.30	1.46	90	100	..	93	3
Sorghum grain, combine types	0.02	0.32	1.73	..	..	..	..	..	..
Sorghum seed, Norghum	..	..	..	..	74	80	39	92	4
Sorghum seed, sweet	0.02	0.28	1.52	0.37	61	66	100	89	2
Sorghum gluten feed	0.09	0.59	3.98	..	..	..	..	..	..
Sorghum gluten meal	0.02	0.17	6.64	..	..	..	..	..	..
Soybean seed	0.25	0.59	6.06	1.50	89	88	..	67	35
Soybean flour, medium in fat	..	..	7.66	..	..	..	..	..	..
Soybean flour, solvent extracted	..	..	7.76	..	..	..	..	..	..
Soybean mill feed, chiefly hulls	..	..	1.92	..	..	..	..	..	..
Soybean oil meal, exp. or hydr., all analyses	0.27	0.63	7.04	1.77	84	85	73	91	67 †
Soybean oil meal, solvent, all analyses	0.29	0.64	7.31	1.92	92	47	87	94	26 †
Soybean oil meal, solvent, 44% protein guarantee	0.26	0.63	7.31	1.92	..	..	..	..	..
Soybean oil meal, exp. or hydr., 43% protein guarantee	..	..	7.02	..	..	..	..	..	..
Soybean oil meal, exp. or hydr., 41% protein guarantee	0.28	0.59	7.04	..	..	..	..	..	..
Soybean oil meal, exp. or hydr., 41% protein guarantee, with added calcium carbonate	..	..	7.07	..	..	..	..	..	..
Soybean oil meal, dehulled, solvent, 50% protein guarantee	..	..	8.06	..	..	..	..	..	..
Starfish meal	15.70	0.45	4.90	..	..	..	..	..	..
Sudan-grass seed	..	..	2.27	..	..	..	..	..	..
Sunflower seed	0.17	0.52	2.69	0.66	..	..	..	..	..
Sunflower seed, hulled	0.20	0.96	4.43	0.92	..	..	..	..	..
Sunflower-seed oil meal, from well-hulled seed	0.26	1.22	7.92	..	91	87	19	53	24 †
Sunflower-seed oil cake, from unhulled seed, solvent	..	..	3.14	..	83	85	21	36	22 †
Sweet potato meal, or dried sweet potatoes	0.15	0.14	0.78	..	14	74	37	90	40
Sweet potato pomace, dried, from starch manufacture	..	..	0.40	..	..	..	..	..	..

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Tankage, or meat meal, digester process, 60% protein grade	92.8	50.5	65.8	0.3	59.4	7.5	1.9	2.6	21.4	127
Tankage, digester process, 60% protein grade, adulterated with paunch contents *	94.0	49.2	64.7	0.3	59.3	7.3	5.5	5.3	16.6	8
Tankage, digester process, 60% protein grade, adulterated with calcium carbonate *	94.3	48.8	66.1	0.4	57.4	8.1	3.7	4.5	20.6	11
Tankage, digester process, or meat meal, 55% protein grade *	94.5	48.1	68.8	0.4	56.6	9.9	2.1	4.5	21.4	10
Tankage with bone, digester process, or meat-and-bone meal, 50% protein grade *	93.8	42.8	62.3	0.5	50.3	9.4	2.6	3.9	27.6	21
Tankage with bone, digester process, or meat-and-bone meal, 45% protein grade *	93.9	36.4	64.1	0.8	45.5	14.3	2.4	4.8	26.9	16
Tankage with bone, digester process, or meat-and-bone meal, 40% protein grade *	94.7	34.3	61.3	0.8	42.9	14.1	2.2	4.1	31.4	8
Tomato pomace, dried *	94.7	16.0	56.6	2.5	22.6	14.5	30.5	23.8	3.3	8
Velvet bean seeds and pods (velvet bean feed)	90.0	13.4	73.8	4.5	18.1	4.4	13.0	50.3	4.2	73
Velvet beans, seeds only	90.0	19.0	81.7	3.3	23.4	5.7	6.4	51.5	3.0	10
Vetch seed *	90.7	24.0	64.0	1.7	29.6	0.8	5.7	51.5	3.1	2
Whale meal *	91.8	66.7	80.8	0.2	78.5	6.7	0	3.1	3.5	1
Whale solubles, condensed *	52.6	38.4	42.7	0.1	43.1	1.3	0	4.1	4.1	1
Wheat, average of all types	89.5	11.1	80.0	6.2	13.2	1.9	2.6	69.9	1.9	..
Wheat, hard spring, chiefly northern plains states *	90.1	13.3	80.7	5.1	15.8	2.2	2.5	67.8	1.8	185
Wheat, hard winter, chiefly southern plains states *	89.4	11.3	79.6	6.0	13.5	1.8	2.8	69.2	2.1	86
Wheat, soft winter, Miss. Valley and eastward *	89.2	8.6	80.1	8.3	10.2	1.9	2.1	73.2	1.8	181
Wheat, soft, Pacific Coast states *	89.1	8.3	79.9	8.6	9.9	2.0	2.7	72.6	1.9	57
Wheat bran, all analyses	90.1	13.3	66.9	4.0	16.4	4.5	10.0	53.1	6.1	146

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phos-phorus	Nitro-gen	Potas-sium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Tankage, or meat meal, digester process, 60% protein grade	6.37	3.23	9.50	0.46	85	84	..	..	14 †
Tankage, digester process, 60% protein grade, adulterated with paunch contents	..	..	9.49	..	..	..	..	..	..
Tankage, digester process, 60% protein grade, adulterated with calcium carbonate	..	..	9.18	..	..	..	..	..	..
Tankage, digester process, or meat meal, 55% protein grade	7.33	3.93	9.06	..	..	..	..	..	..
Tankage with bone, digester process, or meat-and-bone meal, 50% protein grade	10.47	5.18	8.05	..	..	..	..	..	..
Tankage with bone, digester process, or meat-and-bone meal, 45% protein grade	..	..	7.28	..	..	..	..	..	..
Tankage with bone, digester process, or meat-and-bone meal, 40% protein grade	13.01	5.45	6.86	..	..	..	..	..	..
Tomato pomace, dried	..	..	3.62	..	..	..	..	..	..
Velvet bean seeds and pods (velvet bean feed)	0.24	0.38	2.90	1.20	74	80	67	87	24
Velvet beans, seeds only	..	..	3.74	..	81	64	72	97	2 †
Vetch seed	..	..	4.74	..	..	..	..	..	..
Whale meal	0.56	0.57	12.56	..	..	..	..	..	..
Whale solubles, condensed	..	..	6.90	..	..	..	..	..	..
Wheat, average of all types	0.04	0.39	2.11	0.42	84	81	70	91	10
Wheat, hard spring, chiefly northern plains states	0.04	0.40	2.53	..	..	..	..	..	..
Wheat, hard winter, chiefly southern plains states	0.05	0.42	2.16	..	..	..	..	..	..
Wheat, soft winter, Miss. Valley and eastward	..	0.29	1.63	..	..	..	..	..	..
Wheat, soft, Pacific Coast states	..	..	1.58	..	..	..	..	..	..
Wheat bran, all analyses	0.13	1.29	2.62	1.23	81	83	49	76	10

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio	Average total composition: Protein	Fat	Fiber	N-free extract	Mineral matter	No. of anal.
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	1:	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Wheat bran, hard wheat, chiefly hard spring wheat *	90.5	14.1	67.5	3.8	17.4	4.9	10.5	51.4	6.3	28
Wheat bran, soft wheat *	90.5	11.8	66.9	4.7	14.6	3.9	8.9	57.1	6.0	5
Wheat bran and screenings *	89.2	13.0	65.6	4.0	16.1	3.9	9.6	53.4	6.2	265
Wheat brown shorts	88.5	13.9	74.2	4.3	16.4	4.0	6.8	57.1	4.2	6
Wheat brown shorts and screenings *	88.3	13.3	73.6	4.5	15.7	4.6	7.5	55.2	5.3	8
Wheat flour, graham *	88.1	11.5	85.8	6.5	12.5	1.9	1.8	70.4	1.5	7
Wheat flour, low grade	88.4	14.2	87.1	5.1	15.4	1.9	0.5	69.7	0.9	14
Wheat flour, white *	88.0	9.9	86.7	7.8	10.8	0.9	0.3	75.6	0.4	..
Wheat flour middlings	90.1	15.4	79.2	4.1	17.5	4.5	4.3	60.0	3.8	14
Wheat flour middlings and screenings *	89.6	15.0	78.4	4.2	17.1	4.4	5.2	59.1	3.8	8
Wheat germ meal *	89.9	24.5	83.1	2.4	27.8	9.2	3.3	44.4	5.2	6
Wheat germ oil meal *	89.1	26.8	78.5	1.9	30.4	4.9	2.6	46.4	4.8	1
Wheat gray shorts	89.1	13.8	77.2	4.6	16.4	3.9	6.0	58.6	4.2	10
Wheat gray shorts and screenings *	88.5	13.6	76.4	4.6	16.2	3.8	6.1	58.0	4.4	602
Wheat mixed feed, all analyses	90.7	13.1	70.1	4.4	15.8	4.3	8.3	57.1	5.2	19
Wheat mixed feed, hard wheat *	91.0	13.9	71.0	4.1	16.8	4.9	8.9	55.3	5.1	9
Wheat mixed feed and screenings *	90.2	13.4	70.3	4.2	16.2	4.7	8.1	56.1	5.1	30
Wheat red dog *	89.6	15.8	85.5	4.4	17.9	4.2	3.5	60.5	3.5	15
Wheat screenings, good grade	90.4	10.0	68.7	5.9	13.9	4.7	9.0	58.2	4.6	140
Wheat standard middlings	90.1	14.3	77.2	4.4	17.2	4.9	7.3	55.9	4.8	24
Wheat standard middlings, hard wheat *	90.5	14.5	77.6	4.4	17.5	5.2	8.0	54.9	4.9	5
Wheat standard middlings and screenings *	90.3	14.1	77.5	4.5	17.0	4.9	7.4	56.3	4.7	55
Wheat white shorts	89.4	14.5	86.0	4.9	16.5	3.0	2.4	65.1	2.4	7
Whey, from cheddar cheese *	6.9	0.8	6.5	7.1	0.9	0.3	0	5.0	0.7	..
Whey, skimmed *	6.6	0.8	5.9	6.4	0.9	0.03	0	5.0	0.7	..
Whey, condensed *	69.1	9.4	56.9	5.1	10.4	0.8	0	49.2	8.7	11
Whey, dried *	93.0	11.5	78.3	5.8	12.8	0.7	0.2	70.1	9.2	24
Whey product, dried *	90.7	13.8	71.9	4.2	15.3	1.3	0.3	59.4	14.4	7
Yeast, brewers', dried	94.0	38.6	72.8	0.9	44.9	0.7	2.7	38.8	6.9	16
Yeast, dried, with added cereal *	90.3	10.6	73.4	5.9	12.3	3.8	3.3	68.4	2.5	18
Yeast, irradiated, dried *	93.9	41.9	71.7	0.7	48.7	1.1	5.5	32.2	6.4	12
Yeast, molasses distillers, dried *	91.0	33.4	63.3	0.9	38.8	1.9	6.1	30.2	14.0	5
Yeast, torula, dried *	92.3	39.9	69.8	0.7	46.4	1.2	2.5	34.0	8.2	1

TABLE I. Average composition and digestible nutrients—*continued.*

Feeding stuff	Mineral and fertilizing constituents				Digestion coefficients				
	Calcium	Phosphorus	Nitrogen	Potassium	Protein	Fat	Fiber	N-free extract	No. of trials
Concentrates—Cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Wheat bran, hard wheat, chiefly hard spring wheat	0.13	1.35	2.78	..	..	..	..	..	..
Wheat bran, soft wheat	..	..	2.34	..	..	..	..	..	..
Wheat bran and screenings	0.14	1.21	2.58	..	..	..	..	..	..
Wheat brown shorts	..	..	2.62	..	85	85	60	85	6
Wheat brown shorts and screenings	..	..	2.51	..	..	..	..	..	..
Wheat flour, graham	0.04	0.36	2.00	0.46	..	..	..	..	..
Wheat flour, low grade	..	..	2.46	..	92	87	50	99	2
Wheat flour, white	0.02	0.09	1.73	0.05	..	..	..	..	..
Wheat flour middlings	0.09	0.71	2.80	0.89	88	86	54	88	4
Wheat flour middlings and screenings	0.14	0.68	2.74	..	..	..	..	..	..
Wheat germ meal	0.08	1.11	4.45	0.29	..	..	..	..	..
Wheat germ oil meal	..	..	4.86	..	..	..	..	..	..
Wheat gray shorts	0.13	0.84	2.62	..	84	92	54	89	6
Wheat gray shorts and screenings	..	..	2.59	..	..	..	..	..	..
Wheat mixed feed, all analyses	0.11	1.09	2.53	..	83	86	..	78	4
Wheat mixed feed, hard wheat	0.11	1.09	2.69	..	..	..	..	..	..
Wheat mixed feed and screenings	0.11	0.96	2.59	..	..	..	..	..	..
Wheat red dog	0.07	0.51	2.86	0.60	..	..	..	..	..
Wheat screenings, good grade	0.44	0.39	2.22	..	72	88	6	84	10 †
Wheat standard middlings	0.09	0.93	2.75	1.04	83	85	60	88	7
Wheat standard middlings, hard wheat	0.08	0.82	2.80	..	..	..	..	..	..
Wheat standard middlings and screenings	0.15	0.88	2.72	..	..	..	..	..	..
Wheat white shorts	..	..	2.64	..	88	92	34	99	2
Whey, from cheddar cheese	0.05	0.04	0.14	0.19	..	..	..	..	..
Whey, skimmed	..	..	0.14	..	..	..	..	..	..
Whey, condensed	0.56	0.85	1.66	..	..	..	..	..	..
Whey, dried	0.86	0.72	2.05	..	..	..	..	..	..
Whey product, dried	1.50	1.00	2.45	..	..	..	..	..	..
Yeast, brewers', dried	0.13	1.56	7.18	..	86	0	0	88	25 †
Yeast, dried, with added cereal	0.09	0.45	1.97	..	..	..	..	..	..
Yeast, irradiated, dried	0.07	1.55	7.79	2.14	..	..	..	..	..
Yeast, molasses distillers, dried	..	..	6.21	..	..	..	..	..	..
Yeast, torula, dried	..	..	7.42	..	..	..	..	..	..

Table II. Estimated Net-energy Values and Feed Evaluation Factors

Estimated net-energy values.—For the reasons stated in Chapter III, it is the belief of the author that net-energy values are more accurate than total digestible nutrients for comparing the value of a roughage with that of a concentrate for productive purposes. (77–80) This may also be the case when a high-grade concentrate, containing but little fiber, is to be compared with a concentrate which has appreciably more fiber.

The following table of estimated net-energy values of the most important feeding stuffs has therefore been prepared by the author. These estimates are based upon a study of all the available data that provide information concerning the relative values of these feeds for productive purposes. It should be distinctly understood that many of the values are only approximate and are subject to revision and change, as additional data may become available.

It will be noted that the first two columns of figures give the percentage of dry matter and the percentage of digestible protein in each feed. These values are the same as those given in Appendix Table I, and they are repeated here for ease in computing rations according to the net-energy method, by the use of the net-energy feeding standards presented in Appendix Table III. The figures for digestible protein are the values for *digestible crude protein,* and not *digestible true protein.* (18)

These data indicate the relative net-energy values of the various feeding stuffs when each feed is used in a complete, well-balanced ration, which provides adequate supplies of protein, minerals, and vitamins. If any feed is improperly used or if it forms part of a ration that has nutritive deficiencies, its value may be much less than shown in this table. Also, when a protein-rich feed is fed in great excess of the amount necessary to balance the ration, it may have a considerably lower net-energy value than here estimated.

Attention should be called to the fact that these estimated net-energy values indicate merely the worth of the various feeds as sources of energy, and do not take into consideration the values of the feeds as sources of protein, minerals, and vitamins. Thus, the high-grade protein-rich concentrates have no higher net-energy values than such feeds as corn and wheat, which are relatively low in protein.

It should also be borne in mind that net-energy values do not indicate the relative efficiency of different feeds for maintaining farm animals in cold weather. (75) In comparing the values of feeds for maintenance, the total digestible nutrient values given in Appendix Table I should be used.

These net-energy values are primarily for cattle and sheep, but may also be employed in computing rations for horses and swine, when used with the net-energy recommendations given in the last column of the Morrison feeding standards. (Appendix Table III.)

Net-energy values for dairy cows.—As has been shown in Chapter III, the various feeding stuffs have materially higher net-energy values for milk production than for the fattening of animals. (78) However, the relative net-energy values of most feeds for milk production and for fattening are probably not far different. Where it is believed that the relative net-energy value of a particular feed for dairy cows differs materially from its value for fattening cattle or sheep, the estimated net-energy value of the feed for dairy cows is shown separately.

It seems probable that the relative net-energy value, or productive value, of good-quality hay for dairy cows is somewhat higher in relation to the values of concentrates, than in the case of fattening cattle and sheep. However, there is not sufficient definite information on this question to warrant separate figures for the net-energy value of such hay for dairy cows.

Net-energy values of roughages.—In the case of dry roughages, these values are based upon the results se-

cured when the roughages are fed in mangers or racks so as to prevent undue waste. The estimated value for each roughage takes into consideration the amount of the feed that is usually refused when it is thus fed. For such coarse roughage as dry corn fodder, dry corn stover, sorghum fodder, or sorghum stover, the estimates are for roughage that has been chopped or shredded to reduce the wastage. Likewise, the values for the various grains are based upon the grain being ground or crushed when such preparation is necessary to prevent poor utilization.

Estimating net-energy values.—It has been shown previously that the net-energy values have been actually determined for only a very few feeds by investigations with a respiration apparatus or a respiration calorimeter. Also, probably because of the complex nature of such investigations, there have been rather wide differences in the net-energy values thus directly determined for these few feeds. In arriving at the net-energy values given in this table, it has therefore been necessary to utilize all possible data bearing on the values of the various feeds for productive purposes.

Where the relative values of different feeds have been definitely determined by means of a sufficient number of suitable feeding experiments, the net-energy values have been based primarily on these experiments. For other feeds the values have been computed from the content of total digestible nutrients given in Appendix Table I, by the use of factors based on the chemical composition of the particular feeding stuff and on all available information concerning its feeding value.

In making these estimates careful consideration has been given to the net-energy values, or production values, computed by Fraps. (**86**) Due attention has also been given to the estimates made many years ago by Kellner and Armsby and to the Scandinavian feed-unit values. (**82–84**)

Feed evaluation constants.—In order to select economical rations for livestock, it is necessary to determine which of the available feeds that are otherwise satisfactory provide nutrients at least expense. It has been emphasized previously that the best guides to the relative values of various feeds for any class of stock are furnished by the results of actual feeding experiments with that particular class of stock. (**58–59**) Extensive summaries of such experiments are therefore presented in Part II of this volume, which show the results that have been secured with most of the important feeding stuffs when fed to the various classes of stock.

The relative values of the same two feeds for various classes of farm animals may differ to a considerable extent. Before deciding upon the feeds to use in a ration for any kind of stock, one should therefore find what definite information is given in Part II concerning the values of the different available feeds for the particular kind of livestock.

The relative values of many feeds have not yet been determined accurately for the various classes of stock. In deciding which of such feeds are most economical, one must base his judgment on the amounts of digestible nutrients they furnish and on the general information that is available concerning the usefulness of the respective feeds for the particular class of stock.

When protein-rich feeds are more expensive than feeds low in protein, a method of comparison should be used that considers both the amount of digestible protein in a feed and also the amount of total digestible nutrients or net energy it supplies. The Petersen method of valuing feeds, which has been explained in Chapter XII, is a convenient method of making such comparisons. (**336**) The fourth and fifth columns of figures in the following table therefore give the constants, or factors, for evaluating the most important feeds by this method.

These constants have been computed with dent corn of Federal Grade No. 2 and solvent-process soybean oil meal as the base or standard feeds. It is the belief of the author that net-energy values provide a more accurate basis

for feed evaluation than do total digestible nutrients. These constants have therefore been computed from the average percentages of digestible protein and the estimated net-energy values which are given in the second and third columns of this same table.

The method of using these constants in comparing the economy of various feeds has been explained in Chapter XII. (338–342)

Using feed evaluation constants.—To illustrate the use of the feed evaluation constants further, let us assume that ground dent corn (Grade No. 2) is worth $58.00 per ton and that solvent-process soybean oil meal costs $75.00 per ton. We wish to find the approximate value of brewers' dried grains for dairy cows in comparison with these base feeds, considering its content both of digestible protein and of net energy.

First, multiply $58.00, the price of ground corn per ton, by 0.374, the figure given for brewers' dried grains for *dairy cows* in the fourth column of figures in the table, entitled "Constant for corn." This gives us $21.69. We next multiply $75.00, the price of soybean oil meal per ton, by 0.464, the "Constant for soybean oil meal." This gives us $34.80. We then add these amounts together, and have $56.49 as the approximate value per ton of brewers' dried grains for dairy cows, in comparison with corn and soybean oil meal at the prices assumed.

When there is a minus sign before either the "Constant for corn" or the "Constant for soybean oil meal" the product is to be subtracted, instead of being added. For example, in the case of fish meal, all analyses, the "Constant for corn" is—0.457 and the "Constant for soybean oil meal" is 1.349. Multiplying $58.00, the price of corn per ton, by the constant—0.457, we have as the result—$26.51. Multiplying $75.00, the price of soybean oil meal per ton, by 1.349, gives us $101.18. Subtracting $26.51 from $101.18, we have $74.67 as the approximate value per ton of fish meal.

Net-energy factors in last column.—When protein-rich feeds cost no more than protein-poor feeds, the factors given in the last column of figures should be used for determining the relative values of feeds, instead of the constants in the fourth and fifth columns. These factors show the relative amount of net energy furnished by each feed, in comparison with dent corn of Federal Grade No. 2 taken as 100 per cent.

To illustrate the manner of using these "Net-energy factors" for valuing feeds, let us find the value as a source of net energy for fattening cattle of kafir grain, in comparison with dent corn of Federal Grade No. 2 at $58.00 per ton.

The net-energy factor for kafir in the last column of the table is 97.1 per cent, which means that kafir supplies approximately 97.1 per cent as much net energy as does No. 2 dent corn. Taking 97.1 per cent of $58.00, we find that the value of kafir as a source of net energy is about $56.32, in comparison with No. 2 corn at $58.00 per ton.

TABLE II. Estimated net-energy values and feed evaluation factors

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Dry Roughages	Per ct.	Per ct.	Therms			Per ct.
Alfalfa hay, all analyses	90.5	10.9	40.6	0.296	0.212	50.7
Alfalfa hay, very leafy (less than 25% fiber)	90.5	12.8	43.5	0.286	0.259	54.3
Alfalfa hay, leafy (25–28% fiber)	90.5	11.7	41.5	0.287	0.233	51.8
Alfalfa hay, good (28–31% fiber)	90.5	10.2	40.1	0.308	0.194	50.1
Alfalfa hay, fair (31–34% fiber)	90.5	9.7	38.2	0.294	0.184	47.7
Alfalfa hay, stemmy (over 34% fiber)	90.5	8.2	33.3	0.263	0.153	41.6
Alfalfa leaf meal, good	92.3	16.0	48.2	0.265	0.339	60.2
Alfalfa meal, dehydr., 20% protein guar.	92.2	14.7	47.1	0.286	0.305	58.8
Alfalfa meal, dehydr., 17% protein guar.	92.8	12.3	45.2	0.325	0.241	56.4
Alfalfa meal, 15% protein guarantee	91.6	10.8	43.6	0.343	0.202	54.4
Alfalfa stem meal	91.0	6.1	23.1	0.171	0.118	28.8
Alfalfa and grass hay	89.6	7.7	38.6	0.356	0.127	48.2
Atlas sorghum fodder	75.1	2.9	32.4	0.399	0.005	40.4
Barley hay	90.8	4.0	39.4	0.472	0.020	49.2
Barley straw	90.0	0.7	22.4	0.313	−0.033	28.0
Bean straw, field	89.1	3.0	24.0	0.272	0.028	30.0
Bermuda grass hay, good	90.5	3.6	32.7	0.384	0.024	40.8
Birdsfoot trefoil hay	91.2	9.8	45.4	0.398	0.170	56.7
Bluegrass hay, Kentucky	89.4	4.8	37.3	0.419	0.048	46.6
Bromegrass hay	88.8	5.3	38.0	0.415	0.060	47.4
Carpet grass hay	92.1	3.6	30.5	0.351	0.030	38.1
Clover hay, alsike	88.9	8.1	43.9	0.424	0.125	54.8
Clover hay, crimson	89.5	9.8	39.6	0.312	0.184	49.4
Clover hay, Ladino	89.5	14.2	48.2	0.316	0.288	60.2
Clover, Ladino, and grass hay	88.3	11.3	45.9	0.364	0.211	57.3
Clover hay, red, all analyses	88.3	7.2	41.4	0.412	0.106	51.7
Clover hay, red, leafy (less than 25% fiber)	88.3	9.2	45.0	0.409	0.154	56.2
Clover hay, red, good (25 to 31% fiber)	88.3	6.7	42.3	0.440	0.090	52.8
Clover hay, red, stemmy (over 31% fiber)	88.3	5.8	35.5	0.364	0.080	44.3
Clover hay, sweet (first year)	91.8	11.9	39.7	0.254	0.243	49.6
Clover hay, sweet (second year)	90.7	9.5	33.1	0.224	0.190	41.3
Clover and mixed grass hay, high in clover	89.6	5.5	41.4	0.460	0.058	51.7
Clover and timothy hay, 30 to 50% clover	88.1	4.7	40.8	0.473	0.036	50.9
Corn cobs, ground, fed with efficient supplements	90.4	0	40.1	0.595	−0.095	50.1
Corn fodder, well eared, very dry	91.1	3.8	39.4	0.478	0.014	49.2
Corn fodder, medium in water	82.6	3.3	36.1	0.443	0.008	45.1
Corn fodder, high in water	60.7	2.4	26.6	0.327	0.005	33.2
Corn stover (ears removed), very dry	90.6	2.1	27.5	0.349	−0.006	34.3
Corn stover, medium in water	80.3	2.0	24.1	0.301	0.000	30.1
Corn stover, high in water	59.0	1.4	17.9	0.226	−0.003	22.3
Cottonseed hulls	90.8	0	29.3	0.435	−0.069	36.6
Cowpea hay	90.4	12.3	39.1	0.234	0.255	48.8
Grass hay, mixed, eastern states, good qual.	89.0	3.5	39.3	0.485	0.006	49.1
Grass hay, mixed, second cutting	89.0	7.7	45.0	0.451	0.111	56.2
Hegari fodder	86.3	3.2	38.3	0.479	0.000	47.8
Hegari stover	87.0	1.9	25.8	0.329	−0.007	32.2
Johnson grass hay	90.2	2.9	37.7	0.478	0.007	47.1
Kafir fodder, including grain, very dry	90.0	4.5	39.1	0.454	0.035	48.8
Kafir fodder, high in water	71.7	3.4	33.4	0.400	0.017	41.7
Kafir stover, very dry	90.0	1.9	27.7	0.358	−0.012	34.6
Kafir stover, high in water	72.7	1.3	22.3	0.295	−0.016	27.8
Lespedeza hay, annual, in bloom	89.1	6.4	36.5	0.362	0.095	45.6
Lespedeza hay, sericea	89.2	4.1	34.5	0.397	0.035	43.1
Marsh or swamp hay, good quality	90.2	4.1	33.6	0.383	0.037	41.9
Millet hay, foxtail varieties	87.6	4.9	37.5	0.419	0.050	46.8

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Dry Roughages—Continued	Per ct.	Per ct.	Therms			Per ct.
Millet hay, pearl, or cat-tail	87.2	4.2	37.4	0.437	0.030	46.7
Milo fodder, including grain	88.5	3.0	37.3	0.469	—0.003	46.6
Milo stover	91.0	1.1	25.1	0.342	—0.028	31.3
Mixed hay, good, less than 30% legumes	88.2	4.5	37.3	0.427	0.039	46.6
Mixed hay, good, more than 30% legumes	90.3	7.2	38.6	0.371	0.113	48.2
Mixed hay, excellent, mostly legumes	91.4	10.0	46.2	0.405	0.174	57.7
Native hay, western mt. states, good quality	93.3	5.1	40.9	0.464	0.047	51.1
Native hay, western mt. states, mature and weathered	90.0	1.6	22.0	0.281	—0.007	27.5
Oat hay	88.1	4.9	37.8	0.423	0.049	47.2
Oat hulls	92.8	1.5	19.0	0.240	—0.002	23.7
Oat straw	89.8	0.7	23.3	0.326	—0.035	29.1
Orchard grass hay, good	88.7	4.2	38.3	0.450	0.028	47.8
Pasture grasses and clovers, mixed, from closely-grazed fertile pasture, dried (northern states)	90.0	15.0	58.0	0.439	0.287	72.4
Pasture grasses, mixed, from poor to fair pasture, before heading, dried	90.0	9.6	44.7	0.394	0.166	55.8
Pea hay, field	89.3	10.6	41.3	0.315	0.202	51.6
Pea-and-oat hay	89.1	8.6	39.7	0.347	0.149	49.6
Peanut hay, without nuts, good	90.6	5.4	34.1	0.354	0.072	42.6
Peanut hulls	92.3	1.6	3.8	0.011	0.036	4.7
Prairie hay, western, early-cut	91.1	3.7	36.6	0.439	0.018	45.7
Prairie hay, western, cut in midseason	91.3	2.0	33.8	0.445	—0.024	42.2
Prairie hay, western, mature	91.9	0.9	26.2	0.364	—0.036	32.7
Prairie hay, western, mature and weathered	91.9	0.1	21.3	0.313	—0.048	26.6
Red top hay	91.2	3.3	37.0	0.456	0.006	46.2
Rice hulls	92.0	0.1	2.0	0.027	—0.002	2.5
Rice straw	92.5	0.6	20.8	0.292	—0.032	26.0
Rye straw	92.8	0	9.0	0.134	—0.021	11.2
Sorghum fodder, sweet, dry	88.9	3.3	35.1	0.428	0.010	43.8
Sorghum fodder, sweet, high in water	65.7	2.4	26.6	0.327	0.005	33.2
Soybean hay, good, all analyses	88.1	9.8	34.5	0.236	0.196	43.1
Soybean hay, in bloom or before	88.0	12.0	38.6	0.235	0.248	48.2
Soybean hay, seed well developed	88.0	10.8	36.5	0.238	0.219	45.6
Soybean hay, poor quality	89.0	4.3	23.2	0.223	0.067	29.0
Soybean straw	88.9	1.1	18.5	0.244	—0.012	23.1
Sudan grass hay	89.4	4.3	36.5	0.421	0.035	45.6
Timothy hay, all analyses	89.0	3.0	37.3	0.469	—0.003	46.6
Timothy hay, before bloom	89.0	6.1	44.1	0.483	0.068	55.1
Timothy hay, early bloom	89.0	4.2	39.8	0.473	0.025	49.7
Timothy hay, full bloom	89.0	3.2	38.8	0.486	—0.001	48.4
Timothy hay, in bloom, nitrogen fertilized	89.0	4.8	40.6	0.468	0.040	50.7
Timothy, late bloom to early seed	89.0	2.8	34.5	0.433	—0.002	43.1
Timothy, late seed	89.0	1.9	27.2	0.350	—0.010	34.0
Vetch-and-oat hay, over half vetch	87.6	8.4	39.0	0.343	0.145	48.7
Wheat hay	90.4	3.3	35.0	0.427	0.011	43.7
Wheat straw	92.6	0.3	10.0	0.140	0.015	12.5
Wheatgrass hay, crested, cut early	90.0	6.5	38.1	0.383	0.094	47.6
Wheatgrass hay, western, cut early	88.0	6.0	36.7	0.376	0.083	45.8
Wheat grass, western, mature	88.0	1.1	27.1	0.371	—0.033	33.8
Green Roughages, Roots, Etc.						
Alfalfa, green	24.4	3.5	12.9	0.093	0.069	16.1
Alfalfa, very young	18.0	3.9	11.6	0.063	0.083	14.5
Alfalfa, ½ to full bloom	25.3	3.4	13.0	0.098	0.066	16.2
Alfalfa and bromegrass pasture, half alfalfa	22.5	3.3	12.1	0.087	0.065	15.1

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Green Roughages—Continued	Per ct.	Per ct.	Therms			Per ct.
Alfalfa and timothy pasture, half alfalfa	21.9	3.5	12.5	0.087	0.069	15.6
Barley fodder	22.2	2.3	12.1	0.115	0.036	15.1
Barley pasture	20.0	3.9	11.0	0.054	0.084	13.7
Beet tops, sugar	17.8	1.7	8.5	0.078	0.028	10.6
Beets (roots), common	13.0	1.2	10.5	0.122	0.009	13.1
Beets (roots), sugar	16.4	1.2	13.7	0.170	0.001	17.1
Bermuda grass pasture	25.0	2.0	13.1	0.138	0.025	16.4
Birdsfoot trefoil pasture	20.0	4.6	13.5	0.071	0.098	16.9
Bluegrass, Kentucky, pasture	30.2	4.1	18.2	0.155	0.073	22.7
Bluegrass, Kentucky, headed out	36.4	3.0	17.5	0.175	0.043	21.8
Bluegrass, Kentucky, in seed	42.2	1.7	14.4	0.166	0.014	18.0
Bluegrass, Ky., and white clover pasture	24.0	3.8	14.9	0.114	0.072	18.6
Bluestem pasture, very young	22.0	2.1	13.1	0.135	0.029	16.4
Bluestem pasture, active growth	34.1	1.3	16.4	0.207	−0.002	20.5
Bluestem pasture, mature	50.8	1.1	17.6	0.230	−0.010	22.0
Bluestem, mature and weathered	84.7	0	19.8	0.294	−0.047	24.7
Bromegrass, smooth, young pasture	25.0	3.9	16.5	0.135	0.071	20.6
Bromegrass, smooth, heading out	30.0	2.8	17.3	0.178	0.038	21.6
Bromegrass, smooth, mature	53.0	1.2	18.1	0.235	−0.009	22.6
Cabbage, entire	9.4	1.9	8.1	0.067	0.035	10.1
Carrots, roots	11.9	0.9	10.3	0.127	0.001	12.9
Clover, alsike, pasture	22.0	3.2	14.1	0.119	0.057	17.6
Clover, crimson	17.4	2.3	10.1	0.085	0.041	12.6
Clover, crimson, and rye grass pasture	18.3	3.0	11.9	0.092	0.057	14.9
Clover, Ladino, pasture	16.6	3.3	11.2	0.073	0.067	14.0
Clover, Ladino, and grass pasture, much Ladino	20.0	2.6	11.4	0.096	0.047	14.2
Clover, red, pasture	18.1	2.8	11.9	0.098	0.051	14.9
Clover, red, in bloom	27.3	3.0	16.5	0.161	0.046	20.6
Clover, sweet, before bloom	20.8	3.2	10.8	0.070	0.065	13.5
Clover and mixed grass pasture, well grazed	20.0	3.4	12.1	0.084	0.068	15.1
Corn fodder, dent, all analyses	24.0	1.2	14.2	0.177	0.000	17.7
Corn fodder, dent, in milk	19.9	0.9	11.6	0.147	−0.002	14.5
Corn fodder, dent, dough to glazing	26.9	1.2	16.8	0.216	0.006	21.0
Corn fodder, dent, kernels ripe, well eared	37.7	1.7	23.6	0.302	−0.008	29.5
Corn fodder, flint, all analyses	22.3	1.2	13.2	0.162	0.003	16.5
Corn stover, green, field corn (ears removed)	22.7	0.5	7.8	0.102	−0.004	9.7
Cowpeas	16.3	2.2	9.4	0.078	0.040	11.7
Dallis grass pasture	25.0	2.2	13.6	0.140	0.030	17.0
Fescue, tall, young pasture	25.0	3.2	15.5	0.140	0.054	19.4
Fescue, tall, older	30.0	2.2	14.6	0.155	0.028	18.2
Grama grass, black, growing	49.6	4.1	22.8	0.223	0.062	28.5
Grama grass, black, mature	64.6	2.0	18.1	0.212	0.014	22.6
Grama grass, blue, growing	49.5	4.3	22.1	0.207	0.069	27.6
Grama grass, blue, nearly mature	64.6	2.4	16.9	0.183	0.028	21.1
Grama grass, blue, mature and weathered	85.0	0.4	18.5	0.263	−0.032	23.1
Grasses, mixed, pasture	28.1	3.7	17.1	0.150	0.064	21.3
Grasses, mixed, hay stage	30.8	1.9	17.8	0.211	0.012	22.2
Grasses, mixed, in seed	42.2	1.0	14.3	0.184	−0.005	17.9
Guinea grass	26.8	0.8	9.7	0.121	0.000	12.1
Johnson grass pasture	25.0	2.5	11.7	0.103	0.043	14.6
Kafir fodder	23.6	1.2	12.2	0.147	0.005	15.2
Lespedeza, annual, pasture, before bloom	25.0	2.9	12.4	0.102	0.053	15.5
Lespedeza, annual, in bloom	28.5	1.8	11.1	0.114	0.025	13.9
Lespedeza, annual, seed ripe	37.2	1.6	10.6	0.112	0.020	13.2
Mangels, roots	9.2	0.9	7.1	0.080	0.009	8.9

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors		
				Constant for corn	Constant for soybean oil meal	Net energy factor
Green Roughages—Continued	Per ct.	Per ct.	Therms			Per ct.
Millet, foxtail varieties	29.9	1.8	15.0	0.172	0.015	18.7
Millet, Japanese, fodder	21.7	1.0	10.9	0.134	0.003	13.6
Milo fodder	22.7	0.7	11.1	0.145	−0.006	13.9
Napier grass, immature	22.0	0.7	10.7	0.139	−0.006	13.4
Napier grass, more mature	27.1	0.7	12.1	0.160	−0.009	15.1
Oat pasture, before heading	14.1	2.4	8.0	0.051	0.049	10.0
Oats, headed out	26.6	1.8	14.4	0.163	0.017	18.0
Orchard grass, young pasture	23.9	3.2	13.8	0.115	0.058	17.2
Orchard grass, in bloom	30.5	1.5	14.6	0.175	0.008	18.2
Pasture grasses and legumes, mixed, from well-grazed, fertile pasture, northern states	22.0	3.8	13.1	0.087	0.076	16.4
Pasture grasses and legumes, mixed, from well-grazed, fertile pasture, southern states	25.1	2.9	14.4	0.132	0.048	18.0
Pasture grasses, with small proportion of legumes, fertile pasture, northern states	22.0	2.8	12.7	0.110	0.049	15.9
Pasture grasses, with small proportion of legumes, fertile pasture, southern states	25.0	2.4	13.5	0.133	0.036	16.9
Pasture grasses, from closely-grazed, poor to fair pasture, northern states	30.2	3.2	15.0	0.133	0.055	18.7
Pasture, temporary winter, southern states	17.0	3.8	10.7	0.052	0.082	13.4
Pasture grasses and clovers at hay stage	33.0	2.5	16.6	0.176	0.031	20.7
Pasture grasses, western plains, active growth	35.0	2.3	17.6	0.197	0.023	22.0
Pasture grasses, west. plains, late summer	50.0	1.4	17.3	0.217	−0.001	21.6
Pasture grasses, western plains, mature	65.0	1.1	18.3	0.241	−0.012	22.8
Pasture grasses, western plains, mature and weathered	90.8	0.5	22.5	0.320	−0.039	28.1
Peas, field	17.3	2.9	11.0	0.082	0.056	13.7
Peas and oats	22.7	2.4	12.5	0.118	0.038	15.6
Potatoes, tubers	21.2	1.3	17.4	0.222	−0.004	21.7
Rape	16.3	2.4	11.5	0.103	0.041	14.4
Rape, leaves and leaf stems	15.4	3.5	11.8	0.077	0.071	14.7
Red top pasture	26.0	3.6	15.1	0.123	0.066	18.9
Rutabagas, roots	11.1	1.0	9.5	0.113	0.006	11.9
Rye pasture	19.5	4.0	11.1	0.052	0.087	13.9
Sorghum fodder, sweet	24.9	0.8	15.4	0.206	−0.014	19.2
Soybean forage	24.0	3.2	12.9	0.102	0.060	16.1
Soybeans, before bloom	20.0	2.4	10.9	0.942	0.042	13.6
Sudan grass pasture	21.6	2.4	12.2	0.114	0.039	15.2
Sudan grass, headed to in bloom	23.4	1.4	12.3	0.143	0.010	15.4
Sweet potatoes, roots	31.8	0.2	25.6	0.374	−0.055	32.0
Timothy pasture	23.9	3.5	14.4	0.115	0.065	18.0
Timothy, in bloom	31.5	1.5	16.1	0.197	0.006	20.1
Turnips, roots	9.3	0.9	7.8	0.090	0.007	9.7
Vetch, common	20.4	2.9	10.5	0.074	0.057	13.1
Wheat fodder	31.9	1.5	11.6	0.130	0.015	14.5
Wheat pasture	19.8	3.6	11.0	0.062	0.076	13.7
Wheatgrass, crested, very young	25.1	5.6	17.0	0.095	0.118	21.2
Wheatgrass, crested, headed out	36.9	1.6	16.9	0.206	0.005	21.1
Wheatgrass, crested, mature	60.0	1.7	19.3	0.239	0.003	24.1
Wheatgrass, crested, mature and weathered	80.0	1.2	23.5	0.315	−0.022	29.3
Silages						
Alfalfa, not wilted, no preservative	24.7	2.6	11.1	0.091	0.047	13.9
Alfalfa, wilted	36.2	4.3	17.6	0.140	0.080	22.0

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Silages—Continued	Per ct.	Per ct.	Therms			Per ct.
Alfalfa-molasses, not wilted	26.8	2.7	12.6	0.111	0.047	15.7
Alfalfa, not wilted, grain added	25.5	2.6	12.9	0.118	0.043	16.1
Alfalfa-phosphoric acid	26.8	3.2	11.8	0.085	0.063	14.7
Alfalfa-brome, not wilted	25.0	2.6	14.5	0.142	0.039	18.1
Alfalfa-grass, over half alfalfa, wilted	36.2	4.1	17.4	0.143	0.075	21.7
Alfalfa-timothy-molasses	27.5	2.7	13.0	0.117	0.046	16.2
Atlas sorghum	29.7	1.4	14.8	0.180	0.005	18.5
Atlas sorghum, for *dairy cows or other cattle not followed by pigs*	29.7	1.4	13.9	0.167	0.007	17.4
Beet pulp, ensiled	12.0	1.0	9.0	0.105	0.007	11.2
Clover, Ladino, and grass	29.9	3.9	18.2	0.161	0.067	22.7
Clover, red, not wilted	29.5	2.4	14.7	0.151	0.033	18.4
Clover, red, and grass, wilted	35.1	2.5	18.9	0.210	0.026	23.6
Corn, dent, well-matured, well-eared	28.5	1.3	20.3	0.265	−0.011	25.3
Corn, dent, well-matured, well-eared, for *dairy cows or other cattle not followed by pigs*	28.5	1.3	15.2	0.189	0.001	19.0
Corn, dent, well-matured, fair in ears	26.3	1.1	16.3	0.211	−0.007	20.3
Corn, dent, well-matured, fair in ears, for *dairy cows or other cattle not followed by pigs*	26.3	1.1	13.8	0.168	−0.001	17.2
Corn, dent, well-matured, few ears	26.3	1.1	13.8	0.174	−0.001	17.2
Corn, dent, immature, before dough stage	20.3	0.9	11.0	0.138	−0.001	13.7
Corn stover silage, dent (ears removed)	23.7	0.6	9.1	0.118	−0.005	11.4
Corn ears, snapped, immature	44.8	2.2	31.4	0.404	−0.012	39.2
Corn and sorghum	26.0	1.0	14.8	0.192	−0.007	18.5
Corn and soybeans, mostly corn	26.1	1.4	16.2	0.201	0.001	20.2
Corn and soybeans, mostly corn, for *dairy cows or other cattle not followed by pigs*	26.1	1.4	13.6	0.163	0.007	17.0
Feterita	30.0	1.4	13.7	0.164	0.007	17.1
Grass silage, considerable legumes	25.6	2.0	13.2	0.140	0.025	16.5
Grass silage, considerable legumes, wilted	33.3	2.9	16.2	0.159	0.044	20.2
Grass silage, considerable legumes, wilted, grain added	33.8	3.2	17.9	0.176	0.048	22.3
Grass silage, some legumes, molasses added	25.8	1.9	13.0	0.139	0.023	16.2
Grass silage, small proportion legumes	27.6	1.9	13.3	0.144	0.022	16.6
Grass silage, small pro. legumes, wilted	37.3	2.3	17.9	0.201	0.023	22.3
Hegari	33.4	1.6	15.9	0.191	0.008	19.8
Kafir	29.7	1.1	14.4	0.183	−0.003	18.0
Kafir for *dairy cows or other cattle not followed by pigs*	29.7	1.1	13.5	0.169	−0.001	16.9
Lespedeza, annual	30.2	1.8	11.3	0.117	0.024	14.1
Pea and oat	28.4	2.0	14.9	0.165	0.021	18.6
Pea-vine, from canneries	24.5	1.9	11.2	0.113	0.027	14.0
Sorghum, sweet	25.4	0.8	12.2	0.159	−0.006	15.2
Soybean, not wilted	24.8	2.9	11.7	0.092	0.054	14.6
Soybean, wilted	33.7	3.7	14.8	0.115	0.070	18.5
Sunflower	22.6	1.0	9.2	0.109	0.007	11.5
Timothy, no preservative	30.9	1.8	15.6	0.181	0.014	19.5
Timothy, molasses added	30.0	1.6	14.5	0.170	0.011	18.1
Timothy, wilted	40.8	2.2	20.0	0.235	0.015	25.0
Vetch and oats	26.4	1.5	13.1	0.152	0.011	16.4
Concentrates						
Atlas sorghum grain	89.1	8.8	77.9	0.909	0.065	97.3
Barley, common, not including Pacific Coast states	89.4	10.0	70.5	0.765	0.116	88.0

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Concentrates—Continued	Per ct.	Per ct.	Therms			Per ct.
Barley, common, for *dairy cows*	89.4	10.0	80.1	0.908	0.093	100.0
Barley, Pacific Coast states	89.9	6.9	71.4	0.865	0.026	89.1
Barley, light weight	89.1	9.2	61.5	0.654	0.115	76.8
Beet pulp, dried, fed as not over one-half of concentrates	91.2	4.1	70.5	0.931	−0.051	88.0
Beet pulp, dried, for *dairy cows*	91.2	4.1	76.1	1.014	−0.064	95.0
Beet pulp, molasses, dried, fed as not over one-half of concentrates	92.2	5.9	74.3	0.987	−0.009	92.8
Beet pulp, molasses, dried, for *dairy cows*	92.2	5.9	76.1	0.963	−0.013	95.0
Blood meal	91.6	58.4	55.2	−0.823	1.522	68.9
Brewers' grains, dried, 25% prot., or more	93.0	22.0	60.4	0.278	0.480	75.4
Brewers' grains, dried for *dairy cows*	93.0	22.0	66.9	0.374	0.464	83.5
Brewers' grains, wet	23.7	4.2	14.5	0.097	0.084	18.1
Brewers' grains, wet, for *dairy cows*	23.7	4.2	16.1	0.121	0.081	20.1
Buckwheat, ordinary varieties	88.0	7.4	60.8	0.694	0.066	75.9
Buckwheat, for *dairy cows*	88.0	7.4	66.7	0.782	0.052	83.3
Buttermilk	9.4	3.3	10.4	0.062	0.069	13.0
Buttermilk, dried	92.0	28.6	87.8	0.499	0.601	109.6
Citrus pulp, dried	90.0	2.7	69.7	0.958	−0.089	87.0
Citrus pulp, dried, for *dairy cows*	90.0	2.7	75.0	1.037	−0.101	93.6
Coconut oil meal, hydr. or exp. process	93.0	18.0	70.5	0.540	0.342	88.0
Coconut oil meal, for *dairy cows*	93.0	18.0	77.1	0.638	0.327	96.3
Corn, dent, Grade No. 1	87.0	6.9	81.9	1.022	0.001	102.2
Corn, dent, Grade No. 2	85.0	6.7	80.1	1.000	0.000	100.0
Corn, dent, Grade No. 3	83.5	6.5	78.6	0.984	−0.002	98.1
Corn, dent, Grade No. 4	81.1	6.4	73.9	0.917	0.006	92.3
Corn, dent, soft, or immature	66.1	5.4	58.8	0.721	0.014	73.4
Corn ears, including kernels and cobs (corn-and-cob meal)	86.1	5.4	72.1	0.918	−0.018	90.0
Corn, snapped, or ear-corn chops with husks	89.3	4.4	65.8	0.853	−0.031	82.1
Corn feed meal	87.8	7.0	81.9	1.019	0.004	102.2
Corn gluten feed	90.3	21.3	68.9	0.424	0.440	86.0
Corn gluten feed for *dairy cows*	90.3	21.3	71.1	0.456	0.434	88.8
Corn gluten meal	91.6	36.7	80.2	0.158	0.848	100.1
Corn oil meal, exp. or hydr.	91.6	16.1	73.1	0.632	0.283	91.3
Corn-and-oat feed, good grade	89.4	8.4	74.9	0.875	0.060	93.5
Cottonseed, whole	92.7	17.1	76.6	0.656	0.303	95.6
Cottonseed, whole pressed, 28% protein guarantee	92.4	20.2	56.1	0.264	0.439	70.0
Cottonseed feed, below 36% protein	92.4	27.0	62.8	0.173	0.615	78.4
Cottonseed meal, 43% protein grade, not including Texas analyses	92.8	35.9	76.8	0.130	0.834	95.9
Cottonseed meal, 43% protein grade, Texas analyses	92.6	33.7	76.5	0.188	0.773	95.5
Cottonseed meal, 43% protein grade, solvent process	91.0	33.3	69.0	0.088	0.779	86.1
Cottonseed meal, 41% protein grade, not including Texas analyses	92.9	33.3	71.7	0.128	0.773	89.5
Cottonseed meal, 41% protein grade, Texas analyses	92.2	32.2	69.1	0.120	0.748	86.3
Cottonseed meal, 41% protein grade, solvent process	91.5	32.5	63.3	0.025	0.770	79.0
Cowpea seed	89.0	19.2	75.9	0.586	0.364	94.8
Darso grain	90.0	7.4	73.7	0.886	0.035	92.0
Distillers dried corn grains, without solubles	94.4	19.1	84.0	0.709	0.342	104.9
Distillers dried corn grains, with solubles	92.9	19.4	84.0	0.701	0.350	104.9

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Concentrates—Continued	Per ct.	Per ct.	Therms			Per ct.
Distillers dried rye grains	92.3	14.6	58.5	0.458	0.275	73.0
Distillers dried sorghum grains	94.0	20.4	79.7	0.609	0.389	99.5
Distillers dried corn solubles	92.4	22.5	80.0	0.555	0.447	99.9
Emmer grain	91.1	9.7	67.7	0.732	0.114	84.5
Emmer grain for *dairy cows*	91.1	9.7	72.1	0.797	0.104	90.0
Feterita grain	89.4	9.5	77.8	0.888	0.085	97.1
Fish meal, all analyses	92.0	53.6	70.8	−0.457	1.349	88.4
Flax seed	93.8	21.8	108.3	0.994	0.361	135.2
Hegari grain	89.7	7.5	77.8	0.944	0.028	97.1
Hegari head chops	89.6	7.0	67.2	0.800	0.039	83.9
Hominy feed, 5% fat or more	89.9	7.5	84.5	1.043	0.012	105.5
Kafir grain	89.8	8.9	77.8	0.904	0.068	97.1
Kafir head chops	89.2	6.3	65.8	0.800	0.023	82.1
Kaoliang grain	89.9	8.2	77.8	0.924	0.048	97.1
Linseed meal, exp. or hydr. proc., all anal.	91.1	30.6	77.0	0.282	0.684	96.1
Linseed meal, exp. or hydr., 36% protein guarantee	92.4	31.5	77.1	0.258	0.709	96.3
Linseed meal, solvent, 36% protein guar.	91.0	30.7	71.7	0.201	0.699	89.5
Linseed meal, exp. or hydr., 34% protein guarantee	91.0	30.5	76.8	0.282	0.681	95.9
Linseed meal, exp. or hydr., 32% protein guarantee	91.2	30.0	76.8	0.296	0.667	95.9
Linseed meal and screenings oil feed (linseed feed)	90.6	23.8	63.0	0.266	0.525	78.6
Liver meal, animal	92.4	54.3	90.8	−0.180	1.322	113.4
Malt sprouts	92.6	20.3	63.8	0.376	0.423	79.6
Meat scrap, or dry-rendered tankage, 55% protein grade	94.2	45.0	66.7	−0.276	1.115	83.3
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade	93.7	40.8	65.3	−0.178	1.000	81.5
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade, solvent-extracted	93.7	40.9	50.5	−0.401	1.038	63.0
Milk, cows	12.8	3.3	19.6	0.198	0.047	24.5
Millet seed, hog, or proso	90.4	8.4	72.1	0.834	0.067	90.0
Milo grain	89.0	8.5	77.8	0.916	0.056	97.1
Milo head chops	89.6	7.0	70.8	0.854	0.031	88.4
Molasses, beet (net-energy values probably about the same as for cane molasses)	80.5	4.4	..	...	...	...
Molasses, cane, or blackstrap, for *fattening cattle or sheep, when replacing part of the grain*	73.4	0	56.1	0.833	−0.133	70.0
Molasses, cane, for *fattening cattle, when added to excellent ration*	73.4	0	43.3	0.643	−0.102	54.1
Molasses, cane, for *dairy cows, as not over 10% of concentrate mixture*	73.4	0	71.3	1.058	−0.169	89.0
Oat meal, feeding, or rolled oats	90.8	14.5	91.4	0.949	0.194	114.1
Oat mill by-product (oat mill feed)	93.6	2.7	24.0	0.280	0.020	30.0
Oats, not incl. Pacific Coast states, fed as not over 25% of concentrates, with heavy concentrates	90.2	9.4	80.1	0.924	0.076	100.0
Oats, not incl. Pacific Coast states, *fed as chief grain for meat production*	90.2	9.4	65.7	0.711	0.111	82.0
Oats, not incl. Pacific Coast states, *fed as chief grain to dairy cows*	90.2	9.4	72.1	0.806	0.095	90.0
Oats, Pacific Coast states, *fed as not over 25% of concentrates, with heavy concen.*	91.2	7.0	80.1	0.992	0.009	100.0

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Concentrates—Continued	Per ct.	Per ct.	Therms			Per ct.
Oats, Pacific Coast states, *fed as chief grain for meat production*	91.2	7.0	65.7	0.778	0.043	82.0
Oats, Pacific Coast states, *fed as chief grain to dairy cows*	91.2	7.0	72.1	0.873	0.028	90.0
Oats, light weight	91.2	8.3	59.6	0.651	0.094	74.4
Palm-kernel oil meal	91.4	15.4	69.6	0.600	0.271	86.9
Palm-kernel oil meal, for *dairy cows*	91.4	15.4	72.7	0.646	0.264	90.8
Pea feed, or pea meal	90.0	14.5	70.5	0.639	0.243	88.0
Pea seed, field	90.7	20.1	73.8	0.530	0.394	92.1
Peanut oil meal, 50% protein grade, solvent	93.0	47.6	78.8	−0.169	1.160	98.4
Peanut oil meal, 45% protein grade, exp. or hydr., well hulled	94.0	42.4	86.2	0.087	0.996	107.6
Peanut oil meal and hulls, 45% protein grade, exp. or hydr.	93.4	40.3	76.0	−0.005	0.961	94.9
Peanut oil meal and hulls, 45% protein grade, solvent	93.0	41.9	68.5	−0.122	1.023	85.5
Peanut oil meal and hulls, 41% protein grade, exp. or hydr.	92.3	36.6	73.3	0.059	0.862	91.5
Peanut oil meal and hulls, 41% protein grade, solvent	91.8	28.0	66.2	0.195	0.636	82.6
Peanuts, with hulls	94.1	20.2	103.5	0.968	0.327	129.2
Pineapple bran, or pulp, dried	88.6	0.8	54.2	0.782	−0.106	67.7
Pineapple bran, for *dairy cows*	88.6	0.8	61.0	0.883	−0.122	76.2
Potato meal, or dried potatoes	91.4	3.5	70.4	0.947	−0.068	87.9
Potato pulp, dried	87.7	5.6	70.6	0.890	−0.009	88.1
Rice bran	90.8	8.4	56.7	0.605	0.103	70.8
Rice bran for *dairy cows*	90.8	8.4	64.1	0.715	0.086	80.0
Rice bran, solvent extracted	90.9	9.7	52.5	0.507	0.150	65.5
Rice grain, or rough rice	88.8	6.0	65.7	0.806	0.014	82.0
Rice grain for *dairy cows or work stock*	88.8	6.0	70.2	0.873	0.004	87.6
Rice polishings, or rice polish, for *fattening cattle*	89.8	9.7	70.4	0.772	0.108	87.9
Rice polishings for *dairy cows*	89.8	9.7	80.1	0.916	0.085	100.0
Rice polishings for *swine*	89.8	9.7	89.7	1.058	0.062	112.0
Rye grain	89.5	10.0	70.5	0.765	0.116	88.0
Rye feed	90.4	12.2	61.3	0.567	0.200	76.5
Safflower seed oil meal, from well hulled seed	90.5	37.4	69.4	−0.022	0.916	86.6
Safflower seed oil meal, from partly hulled seed	94.0	30.3	61.8	0.065	0.711	77.2
Screenings, grain, good grade	90.0	9.2	53.4	0.534	0.134	66.7
Screenings, grain, higher in fiber	90.4	8.5	45.2	0.432	0.134	56.4
Sesame oil meal	93.7	39.4	71.3	−0.050	0.946	89.0
Skimmilk, centrifugal	9.5	3.4	10.4	0.059	0.072	13.0
Skimmilk, dried	93.9	29.8	87.8	0.465	0.635	109.6
Sorghum grain, combine types	89.6	8.4	77.8	0.918	0.054	97.1
Sorghum gluten feed	90.7	21.4	75.6	0.520	0.427	94.4
Sorghum gluten meal	90.0	35.3	83.2	0.242	0.802	103.9
Soybean seed	90.0	33.7	87.6	0.352	0.746	109.4
Soybean mill feed, chiefly hulls	90.7	7.9	20.4	0.081	0.175	25.5
Soybean oil meal, solvent, 44% protein guarantee	90.3	42.0	79.6	0.000	1.000	99.4
Soybean oil meal, exp. or hydr., 43% protein guarantee	91.4	36.9	80.2	0.153	0.854	100.1
Soybean oil meal, exp. or hydr., 41% protein guarantee	90.9	37.0	79.3	0.136	0.859	99.0

TABLE II. Estimated net-energy values and feed evaluation factors—*continued*

	Dry matter	Digestible protein	Est. net energy per 100 lbs.	Feed evaluation factors: Constant for corn	Constant for soybean oil meal	Net energy factor
Concentrates—Continued	Per ct.	Per ct.	Therms			Per ct.
Soybean oil meal, dehulled, solvent, 50% protein guarantee	91.7	46.4	80.1	–0.116	1.123	100.0
Sunflower-seed oil meal, from well hulled seed	94.3	45.0	67.3	–0.267	1.114	84.0
Sweet potato meal, or dried sweet potatoes, as substitute for part of the grain	90.2	0.7	76.1	0.110	–0.160	95.0
Tankage, or meat meal, digester process, 60% protein grade	92.8	50.5	65.8	–0.444	1.273	82.1
Tankage, or meat meal, 55% protein grade	94.5	48.1	65.8	–0.376	1.205	82.1
Tankage with bone, or meat and bone meal, 50% protein grade	93.8	42.8	62.3	–0.279	1.064	77.8
Wheat, average of all types	89.5	11.1	80.0	0.875	0.125	99.9
Wheat, for *fattening lambs*	89.5	11.1	72.0	0.757	0.144	89.9
Wheat bran, all analyses	90.1	13.3	56.9	0.470	0.242	71.0
Wheat bran, for *dairy cows*	90.1	13.3	66.9	0.619	0.218	83.5
Wheat bran and screenings	89.2	13.0	55.8	1.809	1.582	69.7
Wheat bran and screenings, for *dairy cows*	89.2	13.0	65.6	1.955	1.559	81.9
Wheat brown shorts	88.5	13.9	66.8	0.601	0.235	83.4
Wheat flour middlings	90.1	15.4	75.2	0.683	0.258	93.9
Wheat germ meal	89.9	24.5	83.1	0.544	0.497	103.7
Wheat gray shorts	89.1	13.8	73.3	0.700	0.217	91.5
Wheat mixed feed	90.7	13.1	60.3	0.527	0.228	75.3
Wheat mixed feed, for *dairy cows*	90.7	13.1	70.6	0.679	0.204	88.1
Wheat red dog	89.6	15.8	85.5	0.825	0.245	106.7
Wheat screenings, good grade	90.4	10.0	58.4	0.585	0.145	72.9
Wheat standard middlings	90.1	14.3	69.5	0.629	0.240	86.8
Wheat standard middlings, for *dairy cows*	90.1	14.3	77.2	0.743	0.222	96.4
Wheat standard middlings and screenings	90.3	14.1	69.5	0.635	0.235	86.8
Wheat white shorts	89.4	14.5	85.9	0.867	0.207	107.2
Whey, from cheddar cheese	6.9	0.8	6.5	0.074	0.007	8.1
Whey, dried	93.0	11.5	78.3	0.839	0.140	97.7
Whey product, dried	90.7	13.8	71.7	0.676	0.221	89.5
Yeast, brewers', dried	94.0	38.6	65.5	–0.113	0.937	81.8
Yeast, molasses distillers, dried	91.0	33.4	53.8	–0.141	0.818	67.2
Yeast, torula, dried	92.3	39.9	59.3	–0.242	0.989	74.0

TABLE III. MORRISON FEEDING STANDARDS FOR FARM ANIMALS

The author first presented in 1915 a set of feeding standards for the various classes of livestock. These standards were revised in 1922 and in 1936. In 1948 the standards were again revised, and calcium, phosphorus, and carotene allowances were added to the recommendations. Certain changes have again been made in the standards presented in this edition of *Feeds and Feeding*, on the basis of recent data concerning the nutrient requirements of certain classes of livestock.

These standards have been prepared by the author to serve as guides in the computation of balanced rations for the practical feeding of the various classes of livestock. It should be distinctly understood that they are not statements of the theoretical minimum nutrient requirements of animals under the most optimum conditions.

It has been emphasized in the various chapters of this volume that feeding stuffs of the same name may differ appreciably from the average composition. Individual animals of the same kind also differ to some extent in ability to digest and utilize feed. To serve as safe guides in stock feeding, the recommendations made in feeding standards should therefore not be statements of the theoretical nutrient requirements, but should provide a margin of safety to cover such differences.

It is believed that the recommendations in the Morrison standards provide reasonable margins of safety.

It should be pointed out that in certain tables of nutrient requirements of livestock, the amounts of nutrients stated are the estimated minimum requirements. In using such tables in making up practical rations, these minimum amounts must be materially increased to provide margins of safety. (1498)

Minimum and more liberal recommendations.—It will be noted that both minimum and more liberal recommendations are given for dry matter, digestible protein, and total digestible nutrients (or net energy). When protein-rich feeds are not unduly expensive in comparison with feeds low in protein, it is wise to supply enough digestible protein to bring the protein of the rations well up toward the higher figures in the standards. On the other hand, when protein-rich feeds are unusually expensive in comparison with farm grains or other feeds low in protein, it may be more economical to provide only enough digestible protein to meet the lower recommendations. (343)

Unless concentrates are very high in price in comparison with roughages, it is generally advisable to include a sufficient amount of concentrates in rations to provide as much total digestible nutrients (or net energy) as recommended in the higher figures of the standards. On the other hand, when grain and other concentrates are unusually high in price in comparison with roughage, it may be most economical to supply no more total digestible nutrients (or net energy) than is recommended in the lower figures. (344)

In general, when as much total digestible nutrients are furnished as recommended in the higher figures, there should be sufficient protein in the ration to approach the higher figures for digestible protein given in the standards.

As the information concerning the requirements of farm animals for calcium, phosphorus, and carotene is still very limited, no range is given in the allowances of these nutrients. The allowances stated show merely the approximate requirements for each class of livestock.

Net-energy recommendations.—For the convenience of those desiring to compute rations according to the net-energy method, the last column of figures in the standards shows the amounts of net energy, expressed in therms, which are advised for various classes of stock. In computing rations by the net-energy method, the net-energy values of feeding stuffs given in Appendix Table II should be used, instead of the total digestible nutrient values given in Appendix Table I.

For the reason stated in Chapter III,

total digestible nutrient values, instead of net-energy values, should always be used in computing maintenance rations for wintering farm animals in sections where the climate is cold. (75) For this reason the net-energy recommendations for wintering various classes of stock are given in parentheses.

Computing economical balanced rations.—Before attempting to work out economical balanced rations for any class of stock, it is important to study carefully the explanations and general hints given in Chapters XI and XII. It is impossible to compute satisfactory balanced rations if reliance is placed only on the mathematical recommendations of any feeding standard. It is emphasized in these chapters that other factors are just as important in determining the efficiency of a ration as are the amounts of digestible protein and of total digestible nutrients (or net energy). Attention must also be given to the general suitability of the feeds to the particular class of stock, to the content of minerals and vitamins in the ration, and in the case of swine and poultry to the quality of protein.

The special rules and hints on feeding the particular class of stock, which are given in the respective chapters of Part III, should be carefully consulted before proceeding to work out a balanced ration. For convenience the following references to important articles discussing balanced rations for the various farm animals are here given:

- Dairy cows, **1008–1048, 1069–1080**
- Dairy calves, **1110–1122**
- Dairy heifers, **1145–1150**
- Beef breeding cows, **1159–1160, 1210–1215**
- Growing beef cattle, **1159–1177, 1219–1223**
- Fattening cattle, **1159–1187, 1226–1237, 1252**
- Breeding ewes, **1264–1266, 1268, 1274–1281, 1304–1308, 1312**
- Fattening lambs, **1264–1265, 1267–1285, 1331–1336**
- Work horses and mules, **1345–1352, 1359–1364**
- Brood mares, **1365**
- Growing colts, **1371–1373**
- Brood sows, **1381–1390, 1397–1417, 1455–1466, 1478–1480**
- Growing and fattening pigs, **1381–1425, 1449–1453, 1481–1487**

Guides to proportions and amounts of concentrates and roughages.—In computing rations one should have in mind the approximate amounts of roughages and of concentrates required by the various classes of animals. It has been shown in the experiments summarized in Part III that for dairy cows and for fattening cattle or lambs the proportion of concentrates to roughages that will be most profitable depends chiefly on two factors. The first is the relative cost of concentrates and roughages, and the second is the quality of the roughage which is available.

In general, the following will indicate the approximate amounts of concentrates and roughages required by the various classes of livestock. Additional suggestions are given in the Example Rations in Appendix Table VII.

Dairy cows in milk will eat about 2 lbs. of good-quality dry roughage daily per 100 lbs. live weight. Silage may be substituted for dry roughage at the rate of 3 lbs. of silage for 1 lb. of dry roughage. A common rule is to feed 1 lb. of hay and 3 lbs. of silage daily per 100 lbs. live weight. Sufficient concentrates should be fed in addition to bring the nutrients up to the standard. (See the *"Grain feeding table for cows not on pasture,"* Appendix Table VIIIa.)

If the roughage is of especially good quality, dairy cows will eat as much as 2.5 lbs. of hay equivalent daily per 100 lbs. live weight, and they then need correspondingly less concentrates. On the other hand, if the roughage is of poor quality, they may eat no more than 1.5 lbs. of hay equivalent daily per 100 lbs. live weight. Their concentrate allowance must then be increased over the amount needed with good roughage.

The amounts of concentrates required daily by cows producing different amounts of milk of the various fat percentages are shown in the grain feeding tables given in Appendix Table VIII.

Dairy calves need a liberal amount of concentrates in addition to plenty of well-cured hay, until they are at least 6 months of age.

Dairy heifers from 6 months to a year of age should be fed 2 to 3 lbs. of concentrates per head daily in addition to an abundance of good roughage. If the roughage is of only fair quality, 4 to 5 lbs. of concentrates per head daily may be needed to produce normal growth. Heifers over a year of age can be wintered, up to 3 or 4 months before calving, on good roughage alone. With roughage which is only fair in quality, 2 to 4 lbs. of concentrates should be fed per head daily in addition.

Beef breeding cows may be wintered satisfactorily on roughage of reasonably good quality, without any concentrates. If the roughage is low in protein, 1 lb. per head daily of protein supplement should be fed, and with poor roughage a small amount of grain may be needed in addition.

Beef calves and yearlings will make fair gains when wintered on roughage alone, if it is of good quality. If the cattle are to be fattened early the next summer, it is usually best to feed in addition a sufficient amount of grain or other concentrates during winter to keep them improving in condition, or degree of fatness. A small amount of protein supplement should be fed when needed to balance the ration.

Fattening cattle should receive 2.1 lbs. or more of concentrates and dry roughage (or equivalent in silage) daily per 100 lbs. live weight, the allowance of concentrates ranging from less than 1 lb. to 1.7 lbs. or more daily per 100 lbs. live weight, depending on the rate of gain desired and the character of the roughage.

Breeding ewes may be wintered satisfactorily on good roughage alone up to 4 to 6 weeks before lambing, if they are in good condition in the fall. During the 4 to 6 weeks before lambing, 0.5 to 0.75 lb. of a suitable concentrate mixture should be fed per head daily. Ewes, not on pasture, that are nursing lambs need 1.0 lb. or more per head daily of concentrates in addition to good roughage.

Fattening lambs averaging 70 to 75 lbs. in weight will consume about 1.4 lbs. per head daily of hay or other dry roughage, when fed all the grain they will eat. They will eat 2.3 lbs. or more of hay per head daily when the grain allowance is restricted. The amounts of feed eaten by smaller or larger lambs will be roughly proportional to their live weights.

Work horses and mules should be fed approximately the following amounts daily of concentrates (including grain and other concentrates) and of hay, per 100 lbs. live weight:

At hard work, 1.00 to 1.40 lbs. of concentrates and about 1.00 lb. of hay.

At medium work, 0.75 to 1.00 lb. of concentrates and about 1.00 to 1.25 lbs. of hay.

At light work, 0.40 to 0.75 lb. of concentrates and 1.25 to 1.50 lbs. of hay.

Idle, chiefly or entirely on roughage, unless it is of poor quality, when some grain must be used.

Swine can make but very limited use of dry roughage, except in the case of brood sows not nursing litters. However, it is very important under most conditions that swine not on pasture be supplied with well-cured legume hay as insurance against any lack of vitamins. The proportion of legume hay that should be included in rations for growing and fattening pigs not on pasture will range from 5 per cent to 10 or 15 per cent, depending on the need of vitamin supplements in the ration. **(1417)** Dry-lot rations for pregnant sows should have at least 10 to 15 per cent of legume hay.

Poultry.—Good-quality alfalfa meal or alfalfa leaf meal, or that from other legumes, is commonly included in poultry rations to supply carotene and to aid in furnishing other vitamins. Otherwise, dry roughage is not generally used in poultry rations.

Sources of recommendations in the standards.—These standards are based

chiefly upon extensive studies, made by and under the supervision of the author, of the results of feeding experiments and other investigations that supply information concerning the nutrient requirements of the various classes of stock. Information is given in the respective chapters of Part III concerning the basis for the recommendations made in the standards for the various classes of stock.

The reports on *"Recommended Nutrient Allowances for Domestic Animals,"* made by special committees of the National Research Council, have been carefully considered in the revision of the standards. Generally, the recommendations for calcium, phosphorus, and carotene are the allowances advised by these committees.

Standards for dairy cows.—The amounts of nutrients required for a cow producing a given amount of milk which contains a certain percentage of fat are found as follows: Add together the maintenance requirements for a cow of the particular live weight (shown in Division **1A** of the standards), and the requirements for producing the given amount of milk (computed from Division **1B**).

For cows during the last 2 to 3 months of pregnancy, the additional allowances stated under Division **1C** should be added to the allowances for maintenance and the allowances for any milk produced.

To illustrate the method of using the recommendations under Division **1A** and Division **1B** of the standards, let us find the amount of digestible protein advised under usual conditions for a 1,200-lb. cow producing 30 lbs. of 3.5 per cent milk daily. As stated in the column headings, the higher amounts of digestible protein and of total digestible nutrients given in the standards are advised under usual conditions. The lower amounts are the minimums advised when protein-rich feeds are unusually expensive, or, in the case of total digestible nutrients, when concentrates are unusually expensive in comparison with hay or other roughages.

For the maintenance of a cow of this live weight, the standard recommends 0.76 lb. digestible protein. For producing each pound of 3.5 per cent milk, the allowance recommended is 0.046 lb. digestible protein. Therefore 30 times this amount, or 1.38 lbs. digestible protein, will be required for the production of 30 lbs. of milk. Adding together the maintenance requirement (0.76 lb.) and the production requirement (1.38 lbs.), we have a total of 2.14 lbs. digestible protein, which is the amount advised for such a cow under usual conditions.

For a cow during the last 2 or 3 months of pregnancy, the same method is followed, except that the allowances shown under Division **1C** are to be added to the allowances for maintenance and the allowances for milk production (if the cow is still producing some milk).

Additional allowances for last 2 to 3 months of pregnancy.—For a cow during the last 2 or 3 months of pregnancy, the same method is followed, except that the allowances shown under Division **1C** are to be added to the allowances for maintenance and the allowances for milk production (if the cow is still producing some milk).

Additional allowances for milking heifers.—Heifers are still making considerable growth, and they therefore need more feed than do mature cows of the same live weights and producing the same amounts of milk. To meet their needs, the allowances stated under Division **1D** should be added to the allowances for maintenance and for milk production given in Divisions **1A** and **1B**.

These additional requirements will be met during the first lactation of heifers by feeding about 2.0 to 2.5 lbs. of additional concentrates or 3 to 4 lbs. of good hay. In their second and third lactations heifers need about half as much additional feed as this. It is especially important to feed heifers with sufficient liberality during the latter part of lactation and in the dry period.

Standards for growing dairy cattle.—The standards for growing dairy cattle provide enough nutrients for normal growth. Young cattle consuming suitable rations which contain the amounts of nu-

trients shown in the standards should reach good size for their breed.

Standards for mature dairy bulls, heavy service.—These standards provide sufficient nutrients for mature bulls used in heavy service, such as for producing semen for artificial breeding associations. A young bull that is still growing will need somewhat more nutrients than a mature bull of the same weight.

Standards for beef cattle.—The standards for wintering beef breeding cows provide sufficient nutrients to enable the cows to gain slightly in weight as pregnancy advances.

The standards for wintering beef calves and for wintering yearling cattle provide sufficient nutrients to produce approximately the rates of gain stated in the table.

The standards for growing beef cattle are intended for young cattle that are being grown rapidly throughout the entire period, and not for cattle that are "roughed through the winter," as is the common practice in most sections of the range area.

The standards for calves being fattened for baby beef are intended for calves that are placed on feed when weighing 300 to 400 lbs., and are then fattened rapidly for marketing at a weight of not over 900 to 1,000 lbs. The recommendations for fattening yearlings are for well-grown yearling cattle which weigh 600 to 750 lbs. when placed on feed, and which are marketed at about 1,100 lbs. in weight. The standards for fattening 2-year-old cattle are for cattle which weigh about 900 lbs. at the start, and are marketed at about 1,200 lbs. During the period when fattening cattle are being gotten on feed, they will consume less nutrients than shown in these standards.

The recommendations for fattening cattle are for animals that are to be fattened rapidly on a liberal amount of grain or other concentrates. Cattle fed a limited amount of concentrates will consume less total digestible nutrients (or net energy) than here shown and will not make maximum gains. (**1184–1186**)

Standards for sheep.—The amounts of nutrients advised for breeding ewes should keep them in thrifty condition.

The recommendations for growing ewe lambs and yearlings provide sufficient nutrients for normal growth.

The standards for fattening lambs are intended for fattening thrifty lambs that weigh about 50 to 65 lbs. at the start, and that are fed a sufficiently liberal amount of concentrates to make them fat at a weight of about 90 lbs. While they are being started on feed, lambs will not consume as much nutrients as shown in the standards.

Standards for horses.—The standards for horses at hard work are for horses actually doing hard work at least 7 to 8 hours a day. Horses working hard for a shorter daily period should be classed as "at medium work" or "at light work," as the case may be. The amounts of nutrients advised for idle horses should keep them in thrifty condition and should prevent loss of weight.

Standards for swine.—The standards for gilts and brood sows provide sufficient nutrients to keep them in thrifty condition.

The recommendations for growing and fattening pigs are intended for full-feeding and not for limited-feeding. Pigs of excellent breeding which are unusually growthy may consume somewhat more nutrients than shown in the standards, when self-fed an excellent ration.

Standards for poultry.—Nutrient allowances for poultry are not commonly stated in terms of digestible protein and total digestible nutrients. Feeding standards for poultry are therefore not included in this table. The nutrient allowances recently advised by a special committee of the National Research Council are given in Chapter XXXVI. (**1498, 1587, 1600**)

TABLE III. Morrison feeding standards

	Digestible protein (Lower amounts, minimum advised. Higher amts., advised under usual conditions.)	Total digestible nutrients (Lower amounts, minimum advised. Higher amts., advised under usual conditions.)	Calcium		Phosphorus		Carotene	Net energy (Lower amounts, minimum advised. Higher amts., advised under usual conditions.)
	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
1. Dairy cows								
A. For maintenance, per head daily								
700-lb. cow ..	.44– .48	5.2– 5.9	6.0	.013	6.0	.013	30	4.2– 4.7
750-lb. cow ..	.47– .51	5.6– 6.3	6.0	.013	6.0	.013	30	4.5– 5.0
800-lb. cow ..	.49– .54	5.9– 6.7	6.0	.013	6.0	.013	32	4.7– 5.4
850-lb. cow ..	.52– .56	6.2– 7.0	6.5	.014	6.5	.014	34	5.0– 5.6
900-lb. cow ..	.55– .59	6.5– 7.3	7.0	.015	7.0	.015	36	5.2– 5.8
950-lb. cow ..	.57– .62	6.8– 7.6	7.5	.017	7.5	.017	38	5.4– 6.1
1,000-lb. cow ..	.60– .65	7.0– 7.9	8.0	.018	8.0	.018	40	5.6– 6.3
1,050-lb. cow ..	.63– .68	7.3– 8.1	8.5	.019	8.5	.018	42	5.8– 6.5
1,100-lb. cow ..	.65– .71	7.6– 8.4	9.0	.020	9.0	.020	44	6.1– 6.7
1,150-lb. cow ..	.68– .73	7.9– 8.7	9.5	.021	9.5	.021	46	6.3– 7.0
1,200-lb. cow ..	.70– .76	8.1– 9.0	10.0	.022	10.0	.022	48	6.5– 7.2
1,250-lb. cow ..	.73– .79	8.4– 9.3	10.3	.023	10.3	.023	50	6.7– 7.4
1,300-lb. cow ..	.75– .82	8.6– 9.6	10.5	.023	10.5	.023	52	6.9– 7.7
1,350-lb. cow ..	.78– .84	8.8– 9.9	10.8	.024	10.8	.024	54	7.0– 7.9
1,400-lb. cow ..	.80– .87	9.0–10.2	11.0	.024	11.0	.024	56	7.2– 8.2
1,450-lb. cow ..	.83– .90	9.3–10.5	11.3	.025	11.3	.025	58	7.4– 8.4
1,500-lb. cow ..	.85– .92	9.6–10.8	11.5	.025	11.5	.025	60	7.7– 8.6
1,550-lb. cow ..	.88– .95	9.8–11.0	11.8	.026	11.8	.026	62	7.8– 8.8
1,600-lb. cow ..	.90– .98	10.0–11.2	12.0	.026	12.0	.026	64	8.0– 9.0
1,650-lb. cow ..	.93–1.00	10.2–11.4	12.3	.027	12.3	.027	66	8.2– 9.1
1,700-lb. cow ..	.95–1.03	10.4–11.6	12.5	.028	12.5	.028	68	8.3– 9.3
1,750-lb. cow ..	.98–1.06	10.6–11.8	12.8	.028	12.8	.028	70	8.5– 9.4
1,800-lb. cow ..	1.00–1.08	10.8–12.0	13.0	.029	13.0	.029	72	8.6– 9.6
B. For milk production per pound of milk. (To be added to allowances for maintenance.)								
For 3.0% milk ..	.040–.052	.26–.28	1.0	.0022	.75	.0017	...	.24–.26
For 3.5% milk ..	.043–.055	.28–.30	1.0	.0022	.75	.0017	...	.26–.28
For 4.0% milk ..	.045–.057	.31–.32	1.0	.0022	.75	.0017	...	.29–.30
For 4.5% milk ..	.048–.059	.33–.35	1.0	.0022	.75	.0017	...	.31–.32
For 5.0% milk ..	.050–.060	.35–.37	1.0	.0022	.75	.0017	...	.33–.35
For 5.5% milk ..	.053–.063	.38–.40	1.0	.0022	.75	.0017	...	.35–.37
For 6.0% milk ..	.055–.064	.40–.42	1.0	.0022	.75	.0017	...	.37–.39
For 6.5% milk ..	.058–.065	.42–.45	1.0	.0022	.75	.0017	...	.39–.41
C. Additional allowances for last 2 to 3 months of pregnancy (To be added to allowances for maintenance and for milk produced.)								
Small cow	.50–.55	5.0–5.5	6.0	.013	6.0	.013	24	4.3–4.7
1,000-lb. cow ...	.55–.60	5.5–6.0	8.0	.018	7.5	.017	30	4.7–5.1
Large cow	.65–.70	6.5–7.0	10.0	.022	8.0	.018	36	5.5–6.0

TABLE III. Morrison feeding standards—*continued.*

	Digestible protein (Lower amounts, minimum advised. Higher amts., advised under usual conditions.)	Total digestible nutrients (Lower amounts, minimum advised. Higher amts., advised under usual conditions.)	Calcium		Phosphorus		Carotene	Net energy (Lower amounts, minimum advised. Higher amts., advised under usual conditions.)
	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
D. Additional allowances for milking heifers (To be added to allowances for maintenance and for milk produced.)								
First lactation . . .	.25–.30	1.5–1.8	3.0	.007	3.0	.007	. . .	1.3–1.5
Second lactation .	.13–.15	0.8–0.9	1.5	.003	1.5	.003	. . .	0.7–0.8

	Requirements per head daily								
	Dry matter	Digestible protein	Total digestible nutrients	Calcium		Phosphorus		Carotene	Net energy
	Lbs.	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
2. Growing dairy cattle									
Weight 50 lbs.	0.8– 1.0	.20– .25	1.0– 1.2	4	.009	3	.007	2	1.2– 1.4
Weight 100 lbs.	1.8– 2.4	.35– .45	1.8– 2.2	7	.015	6	.013	4	2.0– 2.4
Weight 150 lbs.	3.2– 3.8	.45– .55	2.8– 3.2	12	.026	10	.022	6	2.8– 3.2
Weight 200 lbs.	4.9– 6.1	.55– .65	3.6– 4.4	13	.029	10	.022	8	3.5– 4.3
Weight 300 lbs.	7.0– 8.4	.68– .78	4.8– 5.7	13	.029	11	.024	12	4.5– 5.4
Weight 400 lbs.	9.1–11.4	.76– .87	6.0– 7.0	13	.029	12	.026	16	5.5– 6.4
Weight 500 lbs.	10.9–13.1	.80– .90	6.8– 8.2	13	.029	12	.026	20	6.1– 7.4
Weight 600 lbs.	12.6–15.1	.83– .94	7.7– 9.3	13	.029	12	.026	24	6.7– 8.1
Weight 700 lbs.	14.3–17.2	.86– .96	8.4–10.1	13	.029	12	.026	28	7.2– 8.7
Weight 800 lbs.	15.9–19.1	.88– .98	9.1–10.9	13	.029	12	.026	32	7.8– 9.4
Weight 900 lbs.	17.3–20.8	.91–1.01	9.6–11.4	13	.029	12	.026	36	8.3– 9.9
Weight 1,000 lbs.	18.6–22.3	.93–1.03	10.0–12.0	12	.026	12	.026	40	8.6–10.2
Weight 1,200 lbs.	19.9–23.9	.96–1.06	10.9–13.1	12	.026	12	.026	44	9.4–11.3
3. Mature dairy bulls, heavy service									
Weight 1,200 lbs.	16.2–17.8	1.00–1.11	9.8–10.8	10	.022	10	.022	48	8.5– 9.5
Weight 1,400 lbs.	18.4–20.2	1.13–1.25	11.0–12.2	11	.024	11	.024	56	9.6–10.6
Weight 1,600 lbs.	20.6–22.5	1.25–1.38	12.3–13.5	12	.026	12	.025	64	10.7–11.9
Weight 1,800 lbs.	22.7–24.7	1.36–1.51	13.5–14.9	14	.031	14	.031	72	11.8–13.0
Weight 2,000 lbs.	24.7–26.9	1.46–1.62	14.8–16.4	16	.035	16	.035	80	12.9–14.3
Weight 2,200 lbs.	26.5–29.0	1.55–1.72	16.0–17.8	18	.040	18	.040	88	14.1–15.5
Weight 2,400 lbs.	28.3–31.1	1.64–1.83	17.4–19.2	19	.042	19	.042	96	15.1–16.7
Weight 2,600 lbs.	29.9–32.9	1.72–1.92	18.5–20.5	21	.046	21	.046	104	16.2–18.0
4. Wintering pregnant beef cows									
Weight 900 lbs.	13.1–18.4	.65– .70	6.9– 9.7	20	.044	17	.037	55	(5.2– 7.3)
Weight 1,000 lbs.	14.2–20.0	.70– .80	7.5–10.5	20	.044	17	.037	55	(5.6– 7.9)
Weight 1,100 lbs.	15.2–21.5	.75– .85	8.0–11.3	20	.044	17	.037	55	(6.0– 8.5)
Weight 1,200 lbs.	16.3–22.8	.80– .90	8.6–12.0	20	.044	17	.037	55	(6.4– 9.0)
5. Beef cows nursing calves, first 3 to 4 months									
Weight 900–1,100 lbs.	22.0–27.0	1.20–1.40	12.0–15.0	30	.066	24	.053	90	9.6–12.0

TABLE III. Morrison feeding standards—*continued.*

	Requirements per head daily								
	Dry matter	Digestible protein	Total digestible nutrients	Calcium		Phosphorus		Carotene	Net energy
	Lbs.	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
6. Growing beef cattle, fed for rapid growth									
Weight 300 lbs.	7.2– 9.0	.67– .77	5.1– 6.2	18	.040	13	.029	20	4.6– 5.7
Weight 400 lbs.	9.1–11.4	.76– .87	6.2– 7.2	20	.044	15	.033	25	5.6– 6.5
Weight 500 lbs.	10.7–13.0	.81– .92	7.2– 8.4	19	.042	15	.033	30	6.3– 7.4
Weight 600 lbs.	12.4–14.7	.84– .95	8.1– 9.3	18	.040	15	.033	35	7.2– 8.2
Weight 700 lbs.	14.2–16.5	.87– .98	8.9–10.2	17	.037	15	.033	40	7.7– 8.8
Weight 800 lbs.	15.9–18.3	.90–1.00	9.5–10.9	16	.035	15	.033	45	8.2– 9.4
Weight 900 lbs.	17.3–19.7	.93–1.03	10.1–11.5	16	.035	15	.033	50	8.7– 9.9
Weight 1,000 lbs.	18.6–21.0	.95–1.05	10.6–12.0	15	.033	15	.033	55	9.2–10.4
7. Wintering beef calves, to gain 0.75 to 1.00 lb. per head daily									
Weight 300 lbs.	7.0– 8.3	.52– .58	3.9– 4.6	16	.035	12	.026	17	(3.2– 3.8)
Weight 400 lbs.	8.7–10.3	.63– .70	4.8– 5.7	16	.035	12	.026	25	(4.0– 4.8)
Weight 500 lbs.	10.3–12.1	.71– .78	5.7– 6.7	16	.035	12	.026	30	(4.7– 5.6)
Weight 600 lbs.	11.7–13.9	.79– .88	6.5– 7.7	16	.035	12	.026	35	(5.3– 6.2)
8. Wintering yearling beef cattle, to gain 0.50 to 0.75 lb. per head daily									
Weight 600 lbs.	11.6–13.3	.67– .75	6.3– 7.2	16	.035	12	.026	35	(5.0– 5.8)
Weight 700 lbs.	12.9–14.8	.76– .83	7.0– 8.0	16	.035	12	.026	40	(5.6– 6.4)
Weight 800 lbs.	14.2–16.3	.83– .90	7.7– 8.8	16	.035	12	.026	45	(6.2– 7.0)
9. Calves fattened for baby beef									
Weight 400 lbs.	9.6–12.1	1.05–1.15	7.4– 8.6	20	.044	15	.033	25	6.7– 7.8
Weight 500 lbs.	11.3–13.8	1.14–1.26	8.8–10.2	20	.044	16	.035	30	8.1– 9.4
Weight 600 lbs.	13.2–15.8	1.26–1.37	10.2–11.8	20	.044	17	.037	35	9.5–11.0
Weight 700 lbs.	14.8–17.5	1.39–1.52	11.6–13.2	20	.044	18	.040	40	10.9–12.4
Weight 800 lbs.	16.7–19.3	1.52–1.68	12.6–14.4	20	.044	18	.040	45	11.8–13.6
Weight 900 lbs.	17.7–20.3	1.64–1.82	13.5–15.5	20	.044	18	.040	50	12.7–14.6
10. Fattening yearling cattle									
Weight 600 lbs.	15.0–17.6	1.18–1.32	10.7–12.3	20	.044	17	.037	35	9.7–11.2
Weight 700 lbs.	16.5–19.1	1.36–1.52	12.7–14.3	20	.044	18	.040	40	11.7–13.2
Weight 800 lbs.	17.8–20.4	1.52–1.68	14.1–15.9	20	.044	19	.042	45	13.0–14.6
Weight 900 lbs.	18.9–21.7	1.64–1.82	15.4–17.2	20	.044	20	.044	50	14.2–15.8
Weight 1,000 lbs.	20.0–23.0	1.71–1.91	16.0–18.0	20	.044	20	.044	55	14.9–16.7
Weight 1,100 lbs.	21.0–24.0	1.76–1.96	16.5–18.5	20	.044	20	.044	60	15.5–17.4
11. Fattening 2-year-old cattle									
Weight 800 lbs.	19.6–22.2	1.46–1.62	14.1–15.9	20	.044	20	.044	45	12.8–14.5
Weight 900 lbs.	20.7–23.5	1.53–1.78	14.6–17.4	20	.044	20	.044	50	13.3–15.8
Weight 1,000 lbs.	22.0–25.0	1.65–1.85	16.5–18.5	20	.044	20	.044	55	15.2–17.0
Weight 1,100 lbs.	24.0–27.0	1.70–1.90	17.0–19.0	20	.044	20	.044	60	15.6–17.5
Weight 1,200 lbs.	24.0–27.0	1.70–1.90	17.0–19.0	20	.044	20	.044	65	15.8–17.7
12. Pregnant ewes, until 4 to 6 wks. before lambing									
Weight 100 lbs.	2.2– 2.9	.11– .16	1.2– 1.6	3.3	.007	2.6	.006	2.6	(1.0– 1.2)
Weight 110 lbs.	2.5– 3.2	.12– .17	1.4– 1.8	3.4	.007	2.7	.006	2.8	(1.1– 1.4)

TABLE III. Morrison feeding standards—*continued.*

	Requirements per head daily								
	Dry matter	Digestible protein	Total digestible nutrients	Calcium		Phosphorus		Carotene	Net energy
	Lbs.	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
12. Pregnant ewes, until 4 to 6 wks. before lambing —Continued									
Weight 120 lbs.	2.7– 3.4	.13– .18	1.5– 1.9	3.5	.008	2.8	.006	3.0	(1.2– 1.5)
Weight 130 lbs.	2.9– 3.6	.14– .19	1.6– 2.0	3.8	.008	2.9	.006	3.2	(1.2– 1.6)
Weight 140 lbs.	3.1– 3.8	.15– .20	1.7– 2.1	4.0	.009	3.0	.007	3.4	(1.3– 1.6)
Weight 150 lbs.	3.3– 4.0	.16– .21	1.8– 2.2	4.2	.009	3.1	.007	3.6	(1.4– 1.7)
13. Pregnant ewes, last 4 to 6 wks. before lambing									
Weight 110 lbs.	3.5– 3.9	.17– .20	2.1– 2.4	4.4	.010	3.3	.007	6.3	(1.7– 2.0)
Weight 120 lbs.	3.7– 4.1	.18– .21	2.2– 2.5	4.5	.010	3.4	.007	6.8	(1.8– 2.1)
Weight 130 lbs.	3.8– 4.2	.19– .22	2.3– 2.6	4.6	.010	3.5	.008	7.3	(1.9– 2.1)
Weight 140 lbs.	3.9– 4.3	.20– .23	2.4– 2.7	4.7	.010	3.6	.008	7.9	(2.0– 2.2)
Weight 150 lbs.	4.0– 4.5	.20– .24	2.4– 2.8	4.8	.011	3.7	.008	8.5	(2.0– 2.3)
Weight 160 lbs.	4.1– 4.8	.21– .24	2.5– 2.8	4.9	.011	3.8	.008	9.1	(2.1– 2.3)
14. Ewes nursing lambs									
Weight 100 lbs.	3.7– 4.3	.22– .25	2.5– 2.9	6.2	.014	4.6	.010	6.4	2.1– 2.4
Weight 110 lbs.	3.9– 4.5	.22– .26	2.6– 3.0	6.3	.014	4.7	.010	7.0	2.2– 2.5
Weight 120 lbs.	4.1– 4.7	.23– .26	2.7– 3.1	6.5	.015	4.8	.011	7.6	2.3– 2.6
Weight 130 lbs.	4.2– 4.9	.23– .27	2.8– 3.2	6.7	.015	4.9	.011	8.3	2.4– 2.7
Weight 140 lbs.	4.3– 5.0	.24– .28	2.9– 3.3	6.8	.015	5.0	.011	9.0	2.4– 2.8
Weight 150 lbs.	4.4– 5.1	.25– .29	3.0– 3.4	7.0	.015	5.1	.011	9.8	2.5– 2.9
15. Growing ewe lambs and yearlings									
Weight 50 lbs.	2.0– 2.3	.14– .17	1.4– 1.7	2.9	.006	2.6	.006	1.7	1.2– 1.4
Weight 60 lbs.	2.2– 2.5	.14– .18	1.4– 1.8	2.9	.006	2.6	.006	2.0	1.2– 1.5
Weight 70 lbs.	2.4– 2.7	.15– .18	1.5– 1.8	3.0	.007	2.7	.006	2.3	1.3– 1.5
Weight 80 lbs.	2.6– 2.9	.15– .19	1.5– 1.9	3.0	.007	2.7	.006	2.6	1.3– 1.6
Weight 90 lbs.	2.7– 3.1	.16– .19	1.6– 1.9	3.0	.007	2.7	.006	2.9	1.4– 1.6
Weight 100 lbs.	2.8– 3.2	.16– .20	1.6– 1.9	3.1	.007	2.8	.006	3.2	1.4– 1.6
Weight 110 lbs.	2.8– 3.3	.17– .20	1.7– 1.9	3.2	.007	2.8	.006	3.5	1.4– 1.6
Weight 120 lbs.	2.9– 3.3	.17– .21	1.7– 1.9	3.2	.007	2.9	.006	3.8	1.4– 1.6
16. Growing ram lambs and yearlings									
Weight 60 lbs.	2.4– 2.7	.15– .18	1.6– 2.0	3.0	.007	2.7	.006	2.3	1.4– 1.7
Weight 80 lbs.	2.7– 3.1	.16– .19	1.8– 2.2	3.2	.007	2.9	.006	2.8	1.6– 1.9
Weight 100 lbs.	3.0– 3.5	.17– .20	1.9– 2.3	3.3	.007	3.0	.007	3.3	1.6– 2.0
Weight 120 lbs.	3.3– 3.8	.18– .21	2.0– 2.4	3.4	.007	3.1	.007	3.8	1.7– 2.1
Weight 140 lbs.	3.6– 4.2	.19– .22	2.1– 2.5	3.5	.008	3.2	.007	4.3	1.8– 2.2
Weight 160 lbs.	3.8– 4.4	.20– .23	2.2– 2.6	3.6	.008	3.3	.007	4.8	1.9– 2.3
17. Fattening lambs									
Weight 50 lbs.	2.0– 2.4	.17– .19	1.4– 1.6	2.9	.006	2.6	.006	1.5	1.3– 1.5
Weight 60 lbs.	2.2– 2.6	.17– .20	1.5– 1.8	2.9	.006	2.6	.006	1.7	1.3– 1.6
Weight 70 lbs.	2.6– 3.0	.18– .21	1.7– 2.1	2.9	.006	2.6	.006	1.9	1.5– 1.9
Weight 80 lbs.	2.9– 3.3	.19– .22	1.9– 2.3	3.0	.007	2.7	.006	2.1	1.7– 2.1
Weight 90 lbs.	3.1– 3.6	.20– .23	2.1– 2.5	3.0	.007	2.7	.006	2.2	1.9– 2.3
Weight 100 lbs.	3.3– 3.8	.20– .24	2.3– 2.8	3.1	.007	2.8	.006	2.3	2.1– 2.6

TABLE III. Morrison feeding standards—*continued.*

	Requirements per head daily								
	Dry matter	Digestible protein	Total digestible nutrients	Calcium		Phosphorus		Carotene	Net energy
	Lbs.	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
18. Horses, mules, or ponies, idle									
Weight 600 lbs.	6.9– 8.4	.4– .5	4.8– 5.8	9.9	.022	11.0	.024	30	(3.8– 4.6)
Weight 800 lbs.	8.6–10.5	.5– .6	5.9– 7.3	12.2	.027	13.7	.030	40	(4.7– 5.8)
Weight 1,000 lbs.	10.2–12.5	.6– .7	7.1– 8.7	13.7	.030	15.4	.034	50	(5.7– 7.0)
Weight 1,200 lbs.	11.7–14.3	.7– .8	8.1– 9.9	15.7	.035	17.7	.039	60	(6.5– 7.9)
Weight 1,400 lbs.	13.1–16.0	.8– .9	9.1–11.1	17.6	.039	19.8	.044	70	(7.3– 8.9)
Weight 1,600 lbs.	14.4–17.6	.9–1.0	10.0–12.2	19.4	.043	21.8	.048	80	(8.0– 9.8)
Weight 1,800 lbs.	15.8–19.3	1.0–1.1	11.0–13.4	21.1	.047	23.8	.053	90	(8.8–10.7)
19. Horses, mules, or ponies, at light work									
Weight 600 lbs.	8.9–10.9	.5– .6	6.2– 7.6	9.9	.022	11.0	.024	30	5.1– 6.3
Weight 800 lbs.	11.2–13.7	.6– .7	7.7– 9.5	12.2	.027	13.7	.030	40	6.4– 7.9
Weight 1,000 lbs.	13.1–16.0	.7– .8	9.1–11.1	13.7	.030	15.4	.034	50	7.6– 9.2
Weight 1,200 lbs.	15.1–18.4	.8–1.0	10.4–12.8	15.7	.035	17.7	.039	60	8.6–10.6
Weight 1,400 lbs.	16.9–20.6	.9–1.1	11.7–14.3	17.6	.039	19.8	.044	70	9.7–11.9
Weight 1,600 lbs.	18.6–22.8	1.0–1.2	13.0–15.8	19.4	.043	21.8	.048	80	10.8–13.1
Weight 1,800 lbs.	20.5–25.0	1.1–1.3	14.2–17.4	21.1	.047	23.8	.053	90	11.8–14.4
20. Horses, mules, or ponies, at medium work									
Weight 600 lbs.	10.4–12.7	.6– .7	7.2– 8.8	9.9	.022	11.0	.024	30	6.1– 7.5
Weight 800 lbs.	12.9–15.7	.7– .8	9.0–11.0	12.2	.027	13.7	.030	40	7.7– 9.4
Weight 1,000 lbs.	15.3–18.7	.8–1.0	10.6–13.0	13.7	.030	15.4	.034	50	9.0–11.1
Weight 1,200 lbs.	17.5–21.4	.9–1.1	12.2–14.9	15.7	.035	17.7	.039	60	10.4–12.7
Weight 1,400 lbs.	19.6–24.0	1.1–1.3	13.6–16.6	17.6	.039	19.8	.044	70	11.6–14.1
Weight 1,600 lbs.	21.6–26.4	1.2–1.4	15.0–18.4	19.4	.043	21.8	.048	80	12.8–15.6
Weight 1,800 lbs.	23.6–28.8	1.3–1.5	16.4–20.0	21.1	.047	23.8	.053	90	13.9–17.0
21. Horses, mules, or ponies, at hard work									
Weight 600 lbs.	12.0–14.7	.6– .8	8.9–10.9	9.9	.022	11.0	.024	30	7.7– 9.5
Weight 800 lbs.	14.9–18.2	.8–1.0	11.1–13.5	12.2	.027	13.7	.030	40	9.7–11.7
Weight 1,000 lbs.	17.7–21.7	.9–1.1	13.1–16.1	13.7	.030	15.4	.034	50	11.4–14.0
Weight 1,200 lbs.	20.3–24.9	1.1–1.3	15.0–18.4	15.7	.035	17.7	.039	60	13.1–16.0
Weight 1,400 lbs.	22.8–27.9	1.2–1.5	16.9–20.7	17.6	.039	19.8	.044	70	14.7–18.0
Weight 1,600 lbs.	25.1–30.7	1.3–1.6	18.6–22.8	19.4	.043	21.8	.048	80	16.2–19.8
Weight 1,800 lbs.	27.5–33.7	1.4–1.8	20.4–25.0	21.1	.047	23.8	.053	90	17.7–21.8
22. Mares, last quarter of pregnancy, light work									
Weight 600 lbs.	9.5–11.6	.6– .7	6.6– 8.0	10.8	.024	10.8	.024	36	5.5– 6.7
Weight 800 lbs.	11.7–14.3	.7– .8	8.1– 9.9	13.1	.029	13.1	.029	48	6.8– 8.3
Weight 1,000 lbs.	13.8–16.8	.8–1.0	9.5–11.7	15.4	.034	15.4	.034	60	8.0– 9.8
Weight 1,200 lbs.	15.8–19.3	.9–1.1	11.0–13.4	17.7	.039	17.7	.039	72	9.2–11.3
Weight 1,400 lbs.	17.7–21.7	1.1–1.3	12.3–15.1	19.9	.044	19.9	.044	84	10.3–12.7
Weight 1,600 lbs.	19.7–24.1	1.2–1.4	13.7–16.7	22.1	.049	22.1	.049	96	11.5–14.0
Weight 1,800 lbs.	21.6–26.3	1.3–1.5	14.6–17.8	24.2	.053	24.2	.053	108	12.3–15.0
23. Mares nursing foals, light work									
Weight 600 lbs.	13.5–16.5	1.2–1.5	10.7–13.1	16.7	.037	15.2	.034	36	9.3–11.4
Weight 800 lbs.	16.7–20.4	1.5–1.9	13.2–16.2	20.6	.045	18.7	.041	48	11.5–14.1

TABLE III. Morrison feeding standards—*continued.*

	Requirements per head daily								
	Dry matter	Digestible protein	Total digestible nutrients	Calcium		Phosphorus		Carotene	Net energy
	Lbs.	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
23. Mares nursing foals, light work —Continued									
Weight 1,000 lbs.	19.8–24.2	1.8–2.2	15.7–19.1	24.4	.054	22.2	.049	60	13.7–16.6
Weight 1,200 lbs.	22.7–29.7	2.1–2.5	18.0–22.0	28.0	.062	25.4	.056	72	15.7–19.1
Weight 1,400 lbs.	25.4–31.1	2.3–2.8	20.2–24.6	31.4	.069	28.5	.063	84	17.6–21.4
Weight 1,600 lbs.	28.3–34.5	2.6–3.2	22.4–27.4	34.9	.077	31.7	.070	96	19.5–23.8
Weight 1,800 lbs.	30.7–37.5	2.8–3.4	24.4–29.8	37.9	.084	34.4	.076	108	21.2–25.9
24. Growing colts, after weaning									
Mature wt. 600 lbs.									
Weight 200 lbs.	6.7	.77	4.2	7.9	.017	7.3	.016	12	3.6
Weight 400 lbs.	9.1	.57	5.7	8.7	.019	9.1	.020	24	4.8
Mature wt. 800 lbs.									
Weight 200 lbs.	7.2	.93	4.5	9.8	.022	8.8	.019	12	3.9
Weight 400 lbs.	9.9	.80	6.2	10.8	.024	10.8	.024	24	5.3
Weight 600 lbs.	11.7	.65	7.3	10.6	.023	11.2	.025	36	6.1
Mat. wt. 1,000 lbs.									
Weight 200 lbs.	7.5	1.04	4.7	12.3	.027	10.6	.023	12	4.1
Weight 400 lbs.	10.2	.94	6.4	13.4	.030	12.5	.028	24	5.5
Weight 600 lbs.	12.3	.77	7.7	13.4	.030	13.4	.030	36	6.5
Weight 800 lbs.	13.8	.74	8.6	11.6	.026	11.6	.026	48	7.2
Mat. wt. 1,200 lbs.									
Weight 200 lbs.	7.7	1.06	4.8	14.3	.032	12.2	.027	12	4.2
Weight 400 lbs.	10.4	1.03	6.5	16.1	.036	14.6	.032	24	5.6
Weight 600 lbs.	13.3	.93	8.3	16.9	.037	16.3	.036	36	7.1
Weight 800 lbs.	14.7	.87	9.2	15.3	.034	15.3	.034	48	7.7
Weight 1,000 lbs.	16.2	.85	10.1	14.7	.032	14.7	.032	60	8.5
Mat. wt. 1,400 lbs.									
Weight 200 lbs.	8.2	1.22	5.1	17.9	.040	14.9	.033	12	4.4
Weight 400 lbs.	11.0	1.16	6.9	20.5	.045	17.5	.039	24	5.9
Weight 600 lbs.	13.4	1.13	8.4	21.3	.047	18.9	.042	36	7.1
Weight 800 lbs.	15.8	1.05	9.9	20.1	.044	18.7	.041	48	8.4
Weight 1,000 lbs.	17.0	.97	10.6	17.8	.039	17.8	.039	60	8.9
Weight 1,200 lbs.	18.4	.95	11.5	15.9	.035	15.9	.035	72	9.7
Mat. wt. 1,600 lbs.									
Weight 200 lbs.	8.5	1.28	5.3	20.8	.046	17.7	.039	12	4.6
Weight 400 lbs.	11.8	1.43	7.4	24.6	.054	21.4	.047	24	6.4
Weight 600 lbs.	13.9	1.33	8.7	24.6	.054	22.1	.049	36	7.5
Weight 800 lbs.	16.6	1.23	10.4	24.9	.055	23.3	.051	48	8.8
Weight 1,000 lbs.	18.4	1.17	11.5	22.6	.050	22.6	.050	60	9.8
Weight 1,200 lbs.	19.5	1.11	12.2	19.5	.043	20.4	.045	72	10.2
Weight 1,400 lbs.	20.6	1.06	12.9	16.8	.037	19.6	.043	84	10.8
Mat. wt. 1,800 lbs.									
Weight 200 lbs.	9.0	1.39	5.6	24.5	.054	20.4	.045	12	4.9
Weight 400 lbs.	12.3	1.50	7.7	27.9	.062	22.3	.049	24	6.6
Weight 600 lbs.	14.4	1.49	9.0	27.4	.060	22.9	.051	36	7.7
Weight 800 lbs.	17.0	1.44	10.6	27.0	.060	23.9	.053	48	9.0
Weight 1,000 lbs.	19.5	1.40	12.2	26.5	.058	23.9	.053	60	10.4
Weight 1,200 lbs.	20.8	1.34	13.0	23.6	.052	22.6	.050	72	10.9
Weight 1,400 lbs.	22.1	1.26	13.8	21.1	.047	22.0	.049	84	11.6
Weight 1,600 lbs.	22.7	1.18	14.2	18.3	.040	20.6	.045	96	11.9

TABLE III. Morrison feeding standards—*continued.*

	Requirements per head daily								
	Dry matter	Digestible protein	Total digestible nutrients	Calcium		Phosphorus		Caro-tene	Net energy
	Lbs.	Lbs.	Lbs.	Grams	Lb.	Grams	Lb.	Mg.	Therms
25. Wintering pregnant gilts									
Weight 250 lbs.	4.3– 5.1	.56– .69	3.5– 4.3	11.8	.026	9.4	.021	13	3.3– 4.0
Weight 300 lbs.	4.9– 5.9	.65– .79	4.0– 5.0	13.6	.030	10.9	.024	15	3.8– 4.7
Weight 350 lbs.	5.5– 6.5	.73– .90	4.6– 5.6	15.4	.034	12.2	.027	18	4.3– 5.3
26. Wintering pregnant older sows									
Weight 300 lbs.	4.0– 4.8	.49– .60	3.2– 3.9	11.1	.025	8.9	.020	12	3.0– 3.7
Weight 400 lbs.	4.9– 6.1	.63– .76	4.1– 5.0	14.0	.031	11.2	.025	15	3.9– 4.7
Weight 500 lbs.	6.0– 7.4	.76– .92	4.9– 6.0	17.0	.038	13.6	.030	19	4.6– 5.6
Weight 600 lbs.	7.1– 8.7	.89–1.08	5.8– 7.1	19.9	.044	15.9	.035	23	5.5– 6.7
27. Gilts nursing litters									
Weight 350 lbs.	8.9–10.9	1.15–1.40	7.4– 9.1	24.9	.055	19.9	.044	28	7.0– 8.6
Weight 400 lbs.	10.1–12.3	1.23–1.50	8.4–10.3	28.5	.063	22.7	.050	31	8.0– 9.8
28. Older sows nursing litters									
Weight 400 lbs.	9.7–11.8	1.22–1.50	8.0– 9.8	27.0	.060	21.6	.048	28	7.6– 9.3
Weight 500 lbs.	10.6–12.9	1.32–1.50	8.8–10.8	29.7	.066	23.7	.052	35	8.4–10.3
Weight 600 lbs.	11.0–13.4	1.37–1.67	9.2–11.2	30.8	.068	24.6	.054	42	8.7–10.6
29. Growing and fattening pigs									
Weight 25 lbs.	1.6– 2.0	.26– .32	1.4– 1.8	4.1	.009	3.0	.006	.7	1.4– 1.8
Weight 50 lbs.	2.6– 3.2	.37– .45	2.2– 2.6	6.5	.014	4.8	.011	1.0	2.2– 2.6
Weight 75 lbs.	3.5– 4.3	.46– .57	2.9– 3.5	8.8	.019	6.4	.014	1.5	2.8– 3.4
Weight 100 lbs.	4.3– 5.3	.53– .65	3.6– 4.4	10.8	.024	7.9	.017	2.0	3.4– 4.2
Weight 150 lbs.	5.5– 6.7	.64– .78	4.6– 5.6	13.9	.031	10.2	.022	3.0	4.4– 5.3
Weight 200 lbs.	6.1– 7.4	.65– .79	5.0– 6.2	15.3	.034	11.2	.025	4.0	4.8– 5.9
Weight 250 lbs.	6.6– 8.1	.72– .88	5.6– 6.8	16.7	.037	12.3	.027	5.0	5.3– 6.5
Weight 300 lbs.	7.1– 8.7	.76– .93	6.1– 7.3	17.9	.040	13.2	.029	6.0	5.8– 6.9

Table IV. Mineral Matter in Important Feeding Stuffs

Sources of data.—In order to present as accurate information as possible concerning the content of mineral nutrients in various feeding stuffs, a new compilation has been made for this twenty-second edition of *Feeds and Feeding*.

The average percentages of calcium, phosphorus, and potassium determined in this compilation are given in Appendix Table I for all feeds where sufficient data have been reported. The average amounts of certain other mineral elements in the more important feeds are shown in this table (Appendix Table IV), so far as sufficient data are available. For convenience in the use of the table, the percentages of calcium, phosphorus, and potassium in these feeds are repeated here.

The data have been compiled largely from the analyses reported by the American agricultural experiment stations and the United States Department of Agriculture. Much information has been taken from the extensive compilation of the mineral composition of crops made by Doctor K. C. Beeson of the Plant, Soil, and Nutrition Laboratory of the United States Department of Agriculture. (United States Department of Agriculture, Miscellaneous Publication 369, 1941.)

As stated in the introduction to Appendix Table I, data compiled by the Committee on Feed Composition of the National Research Council have been included in this compilation, especially data for by-product concentrate feeding stuffs. The National Research Council has recently published in preliminary form the compilation of analyses of by-product concentrates. The author has aided in this compilation by furnishing data which he has compiled.

Much less information is available concerning the percentages of mineral elements in the many different feeding stuffs than for protein, fat, fiber, nitrogen-free extract, or total mineral matter, data for which are given in Appendix Table I. Also, there is an even greater variation in the percentage of mineral nutrients in feeds of the same name than there is in the percentages of protein, fat, fiber, or nitrogen-free extract. (97, 370–372) The variation is especially great in the case of forages, including hay, pasturage and silage. For example, where the soil is very deficient in phosphorus, the phosphorus content of forages may be so low as to produce serious phosphorus deficiency, unless the lack is corrected.

The data in this table indicate the approximate average content of the various mineral nutrients in the different feeds, when crops are grown on soil which is reasonably well supplied with mineral nutrients.

The data in the table are for the various feeds as they are supplied to livestock, and not the percentages or amounts expressed on the dry matter basis. The content of each mineral is stated in terms of the mineral element, and not as the oxide, as calcium oxide (lime), potassium oxide (potash), etc.

Manganese; copper.—Because the amounts of manganese and of copper in feeds are much smaller than of the other minerals included in the table, the content of manganese and of copper is stated as milligrams per pound of feed, instead of as the percentage. A content of 4.5 milligrams per pound of feed is equivalent to one part in 100,000, or 0.001 per cent.

Cobalt; iodine.—The amounts of cobalt and of iodine in different feeds are not shown in the table, because the amounts of these minerals are highly variable. Also, too few analyses have been reported to indicate the approximate average content. The iodine content of feeds is so exceedingly small that it is measured in parts per billion, instead of in per cent. The cobalt content is also very small, most feeds having much less than one part of cobalt in ten million parts by weight, or less than 0.1 milligram per pound of feed.

The grains and their by-products have only 0.05 milligram or less of cobalt per pound. Linseed meal apparently has more cobalt than other ordinary concen-

trates, having 0.16 milligram per pound. Fish meal and tankage also may have somewhat more cobalt than the grains or their by-products. Legume forages usually have more cobalt than non-legume forages. Alfalfa hay of good quality may have 0.17 milligram per pound.

Fish meal and other sea products have much more iodine than do other common feeds. Fish meal may have 4,000 to 10,000 parts of iodine per billion. The iodine content of the cereal grains is low, ranging from an average of 57 parts per billion parts, on the dry matter basis, for oats to 177 parts per billion for corn. Most hay has slightly more iodine, and the iodine content of straw is appreciably higher.

TABLE IV. Mineral matter content

Feeding stuff	Calcium	Phosphorus	Potassium	Sodium	Chlorine	Sulfur	Magnesium	Iron	Manganese	Copper
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Mg. per lb.	Mg. per lb.
Dry roughages										
Alfalfa hay, all analyses	1.47	0.24	1.97	0.15	0.28	0.29	0.31	0.017	25.4	8.3
Alfalfa hay, before bloom	2.22	0.33	2.14	0.20	0.31	0.57	0.23	0.023	14.1	....
Alfalfa hay, 1/10 to 1/2 bloom	1.47	0.24	1.97	0.14	0.34	0.27	0.23	....	12.7	....
Alfalfa hay, 3/4 to full bloom	1.22	0.22	1.97	...	...	...	0.29	0.014	....	....
Alfalfa leaves	2.22	0.24	2.06	...	...	...	0.40	0.034	32.7	....
Alfalfa meal, dehydrated, 20% protein grade	1.74	0.28	...	...	...	...	.....	0.039	28.6	7.1
Alfalfa meal, dehydrated, 17% protein grade	1.58	0.26	...	...	...	...	.....	0.033	15.0	3.1
Alfalfa stems	0.82	0.17	2.21	...	...	...	0.26	0.015	6.0	....
Alfalfa and bromegrass hay	0.77	0.20	1.66	0.44	0.42	0.21	0.21	0.014	22.3	5.2
Alfalfa and grass hay	1.18	0.24	...	...	...	...	.....	....	14.0	....
Alfalfa and timothy hay	0.83	0.20	...	...	...	...	.....	....	15.0	....
Barley straw	0.33	0.10	1.33	0.13	0.61	0.14	0.07	0.030	6.5	....
Bean straw, field	1.67	0.13	1.02	...	...	0.10	0.12	....	....	....
Bermuda grass hay	0.37	0.19	1.42	...	...	...	0.15	....	....	....
Birdsfoot trefoil hay	1.60	0.20	1.66	...	...	...	0.57	0.013	....	....
Bluegrass hay, Ky., all anal.	0.40	0.27	1.67	0.10	0.55	0.12	0.19	0.025	34.7	4.0
Bluegrass hay, Ky., in seed	0.23	0.20	1.48	0.13	0.38	0.16	0.10	0.015	25.3	....
Bromegrass hay, smooth, all analyses	0.42	0.19	2.26	0.56	0.48	0.17	0.17	0.013	21.0	3.8
Cereals, young, dehydrated	0.66	0.46	...	...	...	...	.....	....	39.9	....
Clover hay, alsike	1.15	0.23	2.44	0.41	0.69	0.19	0.28	0.040	47.2	2.4
Clover hay, crimson	1.23	0.24	2.79	0.35	0.56	0.25	0.26	....	99.9	....
Clover hay, Ladino	1.53	0.29	2.17	...	0.29	0.19	0.46	0.016	72.6	3.5
Clover, Ladino, and grass hay	0.87	0.19	1.70	...	...	...	0.31	0.014	....	....
Clover hay, red, all analyses	1.28	0.20	1.65	0.18	0.33	0.14	0.37	0.010	30.8	4.3
Clover hay, red, before bloom	1.57	0.28	2.26	...	...	...	0.45	....	....	....
Clover hay, red, in bloom	1.34	0.21	1.40	...	...	0.17	0.45	....	....	....
Clover hay, sweet, second year	1.25	0.23	1.78	0.08	0.34	0.41	0.23	0.012	48.5	4.1
Clover and mixed grass hay, high in clover	0.88	0.21	1.43	0.17	0.64	0.13	0.25	0.022	42.1	3.2
Clover and timothy hay, 30 to 50% clover	0.69	0.16	1.61	0.17	0.61	0.13	0.20	0.019	17.2	2.8
Corn cobs, ground	0.11	0.04	0.82	...	...	...	0.06	....	....	....
Corn fodder, well-eared, very dry	0.27	0.16	0.90	0.03	0.17	0.13	0.16	0.009	28.2	2.0
Corn stover, (ears removed) very dry	0.54	0.09	1.49	0.06	0.28	0.15	0.41	0.020	55.8	2.1
Cottonseed hulls	0.13	0.06	0.87	...	...	...	0.13	....	....	....
Cowpea hay	1.37	0.30	1.66	0.20	0.15	0.32	0.37	0.082	....	....
Flax straw	0.67	0.10	1.62	...	...	0.25	0.29	....	....	....
Grass hay, mixed, eastern states, good quality	0.48	0.21	1.20	...	...	0.15	0.16	0.056	29.9	....
Johnson grass hay	0.87	0.26	1.22	...	...	...	0.31	....	....	....
Kafir fodder, very dry	0.35	0.18	1.53	...	...	...	0.26	....	....	....
Lespedeza hay, ann'l, all anal.	0.96	0.18	0.94	...	...	...	0.22	0.026	59.4	....
Lespedeza hay, annual, before bloom	1.03	0.20	1.07	...	...	...	0.21	0.030	72.1	....
Lespedeza hay, annual, in bloom	1.00	0.19	0.94	...	...	...	0.19	0.025	61.2	....
Lespedeza hay, annual, after bloom	0.90	0.15	0.82	...	...	...	0.19	0.030	76.2	....
Lespedeza hay, sericea	0.92	0.22	0.93	...	...	...	0.20	0.026	40.8	....
Marsh or swamp hay, good quality	0.32	0.10	0.69	...	...	...	0.26	0.010	....	....
Millet hay, foxtail varieties	0.29	0.16	1.70	0.09	0.11	0.14	0.20	....	54.9	....

TABLE IV. Mineral matter content—*continued.*

Feeding stuff	Calcium	Phosphorus	Potassium	Sodium	Chlorine	Sulfur	Magnesium	Iron	Manganese	Copper
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Mg. per lb.	Mg. per lb.
Dry roughages—Cont.										
Oat hay	0.21	0.19	0.83	0.15	0.46	...	0.16	0.049	36.6	...
Oat straw	0.24	0.09	2.00	0.48	0.70	0.18	0.18	0.018	13.5	4.5
Orchard grass hay	0.27	0.18	1.92	...	0.38	0.23	0.21	0.012	31.5	6.7
Pasture grasses and clovers, mixed, from closely grazed, fertile pasture, dried (northern states)	0.58	0.32	2.18	...	...	...	0.32	....	....	....
Pasture grasses, mixed, from poor to fair pasture, before heading out, dried	0.41	0.12	0.74	...	...	...	0.10	....	....	....
Pea hay, field	1.22	0.25	1.25	...	...	0.21	0.33	....	....	....
Peanut hay, without nuts, good	1.20	0.24	0.74	...	...	...	0.37	....	....	....
Peanut hulls	0.25	0.06	0.82	...	...	...	0.17	....	....	....
Prairie hay, western, early-cut	0.31	0.19	0.98	...	...	...	0.22	0.008	....	....
Prairie hay, western, cut in midseason	0.33	0.12	...	...	...	...	0.25	....	....	....
Prarie hay, western, mature	0.36	0.08	0.73	...	...	...	0.26	0.010	20.2	9.5
Prairie hay, western, mature and weathered	0.41	0.03	...	...	...	...	.....	....	....	...
Red top hay	0.39	0.20	1.72	0.06	0.07	0.24	0.20	0.014	93.3	1.6
Rye straw	0.26	0.09	0.90	0.12	0.22	0.10	0.07	....	2.8	1.7
Rice straw	0.19	0.07	1.22	0.29	...	...	0.10	....	145.1	....
Sorghum fodder, sweet, dry	0.34	0.14	1.29	...	0.56	...	0.31	....	52.7	....
Soybean hay, good, all anal.	1.10	0.22	1.09	0.09	...	0.26	0.59	0.021	47.6	3.6
Soybean hay, in bloom or before	1.29	0.34	...	...	...	0.16	0.64	....	....	....
Sudan grass hay	0.36	0.27	1.88	...	...	0.05	0.31	0.017	37.1	....
Timothy hay, all analyses	0.35	0.14	1.59	0.16	0.55	0.12	0.17	0.012	19.9	2.0
Timothy hay, full bloom	....	0.20	1.50	0.16	0.55	0.12	0.12	0.014	32.7	2.0
Timothy hay, late seed	0.14	0.15	1.41	0.06	0.52	0.14	0.06	0.024	42.0	....
Timothy & clover hay, ¼ clover	0.58	0.15	1.60	0.17	0.48	0.13	0.24	0.011	23.5	2.8
Vetch hay, common	1.18	0.32	2.22	0.46	...	0.09	0.18	0.028	21.5	4.0
Wheat grass hay, slender	0.30	0.24	2.41	0.75	...	0.10	0.22	....	....	....
Wheat straw	0.15	0.07	0.62	0.13	0.31	0.17	0.11	0.016	23.1	1.3
Green Roughages, Roots, etc.										
Alfalfa, green, all analyses	0.40	0.06	0.53	0.04	0.11	0.09	0.08	0.007	5.5	1.0
Alfalfa, before bloom	0.45	0.07	0.47	0.04	0.07	0.12	0.05	....	2.5	....
Alfalfa, ½ to full bloom	0.51	0.07	0.55	0.04	0.10	0.08	0.07	....	....	....
Apples	0.01	0.01	0.14	0.01	0.01	0.01	0.05	0.001	1.4	1.0
Beet tops, sugar	0.18	0.04	1.03	0.10	0.04	0.10	0.19	0.003	4.4	1.1
Beets (roots), common	0.03	0.04	0.28	0.10	0.03	0.02	0.02	0.002	3.2	0.6
Beets (roots), sugar	0.04	0.04	0.25	0.08	0.08	0.01	0.03	0.001	15.3	0.6
Bermuda grass, in bloom	0.14	0.07	0.55	...	...	...	0.06	....	....	....
Bermuda grass pasture	0.14	0.05	0.55	...	...	...	0.06	....	....	....
Bluegrass, Kentucky, pasture	0.16	0.13	0.59	0.07	...	0.20	0.07	0.005	11.0	1.9
Bluegrass, Ky., headed out	0.09	0.10	0.73	...	...	...	0.04	....	....	....
Bluegrass, Kentucky, in seed	0.08	0.13	0.87	0.06	0.17	0.07	0.005	0.012	....	....
Bluestem past., active growth	0.14	0.05	0.46	...	...	...	.....	0.024	12.9	5.7
Bluestem pasture, mature	0.20	0.07	...	...	...	...	.....	0.033	8.5	3.7
Bluestem pasture, mature and weathered	0.36	0.05	...	...	...	...	.....	0.033	18.0	8.5
Bromegrass, smooth, young pasture	0.12	0.08	0.79	...	...	...	0.08	....	....	....
Cabbage, entire	0.06	0.03	0.24	0.01	0.05	0.11	0.02	0.001	1.3	0.6
Carpet grass pasture	0.10	0.04	0.23	...	...	...	0.06	0.007	....	....
Carrots, roots	0.05	0.04	0.25	0.19	0.06	0.02	0.02	0.002	1.7	0.6

TABLE IV. Mineral matter content—*continued.*

Feeding stuff	Calcium	Phosphorus	Potassium	Sodium	Chlorine	Sulfur	Magnesium	Iron	Manganese	Copper
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Mg. per lb.	Mg. per lb.
Green Roughages, Roots, etc.—Continued										
Clover, alsike, in bloom	0.30	0.06	0.61	0.11	0.18	0.03	0.07	0.011	12.5	0.6
Clover, crimson	0.24	0.05	0.54	0.07	0.11	0.05	0.05	....	10.4	....
Clover, Ladino, pasture	0.21	0.07	0.31	0.02	...	0.02	0.08	0.006	5.4	....
Clover, red, all analyses	0.41	0.06	0.57	0.05	0.20	0.04	0.09	0.008	13.7	1.0
Clover, red, pasture	0.35	0.05	0.47	...	...	...	0.09	....	....	....
Clover, red, in bloom	0.48	0.09	0.54	...	...	0.05	0.14	....	....	....
Clover, sweet, in bloom	0.36	0.07	0.42	0.03	0.11	0.13	0.10	0.004	15.6	1.3
Clover, white, pasture	0.25	0.09	0.38	0.07	0.11	0.06	0.08	0.006	24.8	....
Clover and mixed grass pasture, well grazed	0.23	0.07	0.71	...	...	...	0.17	....	....	....
Corn fodder, dent	0.07	0.05	0.30	0.01	0.05	0.04	0.04	0.002	7.4	0.5
Corn stover, green (ears removed)	0.14	0.02	0.37	0.01	0.07	0.04	0.05	0.005	14.0	0.5
Cowpeas	0.25	0.05	0.27	0.04	0.03	0.05	0.07	0.013	....	....
Dallis grass pasture	0.14	0.05	0.43	...	...	...	0.10	0.004	....	....
Fescue, tall, hay stage	0.09	0.06	0.60	...	...	...	0.07	....	....	....
Kafir fodder	0.09	0.05	0.40	...	...	...	0.07	....	....	....
Lespedeza, ann., before bloom	0.28	0.07	0.32	...	...	...	0.06	0.008	20.2	....
Mangels, roots	0.02	0.02	0.21	0.07	0.13	0.02	0.02	0.002	....	....
Oat fodder	0.10	0.09	0.50	0.05	0.14	0.11	0.07	0.003	38.6	....
Oat pasture, before heading	0.06	0.09	...	...	...	...	0.06	....	....	....
Orchard grass pasture	0.13	0.12	0.63	0.01	...	0.05	0.08	0.004	13.4	....
Pasture grasses and legumes, mixed, from well-grazed, fertile past., northern states	0.14	0.08	0.53	...	...	...	0.07	....	....	....
Pasture grasses and legumes, mixed, from well-grazed, fertile past., southern states	0.19	0.09	0.36	...	0.12	0.06	0.08	0.013	63.5	....
Pasture grasses, from closely-grazed poor to fair pasture, northern states	0.14	0.04	0.25	...	...	...	0.03	....	....	....
Pasture grasses, western plains, young	0.17	0.10	0.45	0.08	0.11	...	0.04	0.014	12.0	8.2
Pasture grasses, western plains, active growth	0.11	0.05	0.56	0.01	0.11	...	.....	....	....	....
Pasture grasses, western plains, mature and weathered	0.28	0.04	0.43	0.01	0.05	...	0.23	0.036	29.2	39.9
Potatoes, tubers	0.01	0.05	0.48	0.02	0.06	0.02	0.03	0.002	4.0	1.7
Rape	0.24	0.07	0.55	...	...	0.11	0.01	0.003	3.4	0.6
Red top, pasture	0.17	0.10	0.55	...	...	...	0.08	....	....	....
Red top, in bloom	0.13	0.09	0.83	...	...	0.10	0.07	....	....	....
Russian thistle	0.66	0.07	2.05	...	...	0.05	0.28	....	....	....
Rutabagas, roots	0.05	0.03	0.21	...	...	0.03	0.02	0.003	0.5	0.4
Rye pasture	0.13	0.10	...	...	...	...	0.07	....	....	....
Rye grass, Italian, pasture	0.13	0.08	0.40	...	...	...	0.07	....	....	....
Sorghum fodder, sweet	0.09	0.03	0.36	0.09	...	...	.....	....	14.8	....
Soybean forage, all analyses	0.26	0.07	0.22	...	...	...	0.13	0.005	13.0	1.0
Soybeans, in bloom	0.36	0.06	0.22	...	...	0.04	0.15	....	....	....
Soybeans, seed well developed	0.38	0.09	0.23	...	...	...	0.24	....	....	....
Sudan grass, headed to bloom	0.09	0.07	0.34	...	...	0.01	0.08	0.003	9.6	....
Sweet potatoes, roots	0.03	0.04	0.38	0.02	0.02	0.04	0.05	0.002	1.6	0.6
Timothy, young pasture	0.14	0.09	0.50	...	...	...	0.06	....	....	....
Timothy, in bloom	0.08	0.08	0.54	0.06	0.20	0.04	0.04	0.005	27.5	1.6
Timothy, in seed	0.08	0.09	0.73	0.03	0.24	0.06	0.03	0.012	21.9	....
Turnips	0.06	0.02	0.26	0.14	0.06	0.04	0.02	0.001	1.8	0.9
Turnip tops	0.49	0.06	0.45	0.17	0.29	0.04	0.12	0.009	27.8	1.2

TABLE IV. Mineral matter content—*continued.*

Feeding stuff	Calcium	Phosphorus	Potassium	Sodium	Chlorine	Sulfur	Magnesium	Iron	Manganese	Copper
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Mg. per lb.	Mg. per lb.
Green Roughages, Roots, etc.—Continued										
Vetch, common	0.27	0.07	0.51	...	...	0.02	0.04	0.008	11.1	0.9
Vetch and oats pasture	0.10	0.13	...	...	...	...	0.06	....	....	....
Wheat pasture	0.09	0.08	...	...	...	...	0.06	....	....	....
Silages										
Alfalfa, not wilted, no preserv.	0.35	0.08	0.58	0.04	0.11	0.09	0.09	0.007	6.0	1.1
Alfalfa, wilted	0.51	0.12	0.84	0.05	0.15	0.13	0.12	0.011	8.5	1.5
Atlas sorghum	0.12	0.06	0.33	0.05	0.04	...	0.10	0.008	6.5	4.7
Clover, Ladino, and grass	0.31	0.07	...	...	...	...	0.09	....	....	....
Clover, red	0.50	0.07	0.53	0.07	0.26	0.05	0.12	0.010	17.8	1.5
Corn, dent, well-matured, all analyses	0.10	0.07	0.30	0.01	0.05	0.04	0.05	0.003	8.8	0.6
Corn, dent, well-matured, well-eared	0.09	0.07	0.27	0.01	0.05	0.04	0.05	0.003	8.8	0.6
Corn, dent, well-matured, fair in ears	0.09	0.06	0.34	...	...	0.03	0.05	....	....	....
Corn, dent, well-mat., few ears	0.09	0.05	0.37	...	...	0.02	0.06	....	....	....
Corn, dent, immature	0.11	0.07	...	...	...	...	0.06	0.010	....	....
Cowpea, wilted	0.48	0.10	0.88	0.07	0.05	0.01	0.13	0.029	....	....
Kafir	0.07	0.05	0.50	...	...	...	0.08	....	....	....
Pea, field	0.38	0.08	0.39	...	...	0.07	0.11	....	....	....
Sorghum, sweet	0.08	0.05	0.26	...	...	...	0.07	0.005	5.4	3.6
Soybean, wilted	0.47	0.12	0.31	0.03	...	0.10	0.15	0.006	19.9	1.4
Sunflower	0.39	0.04	0.66	...	...	0.01	0.02	....	109.0	....
Timothy, wilted	0.23	0.12	0.69	0.08	0.27	0.06	0.06	0.005	16.7	1.0
Concentrates										
Apple pomace, dried	0.10	0.09	0.43	0.22	...	...	0.06	0.027	3.3	....
Babassu oil meal	0.13	0.71	...	...	0.02	...	0.97	0.035	140.1	18.8
Barley, common, not including Pacific Coast states	0.06	0.40	0.49	0.06	0.15	0.15	0.13	0.008	8.0	5.8
Barley feed, high grade	0.03	0.40	0.60	...	...	0.05	0.16	0.010	13.9	....
Beans, field, or navy	0.15	0.57	1.27	0.09	0.04	0.23	0.17	0.012	8.4	4.5
Beans, lima	0.09	0.37	1.70	0.03	0.03	0.20	0.18	0.010	7.3	3.7
Beet pulp, dried	0.69	0.08	0.18	0.17	0.04	0.20	0.27	0.030	15.9	5.7
Beet pulp, molasses, dried	0.57	0.07	1.63	...	...	0.39	0.17	....	....	....
Blood flour, or sol. blood meal	0.64	0.48	0.41	0.33	0.25	0.60	0.04	0.276	2.9	3.7
Blood meal	0.32	0.25	0.09	0.32	0.27	0.33	0.22	0.376	2.4	4.5
Bone meal, cooked	22.96	10.25	0.23	0.74	0.09	0.12	0.35	0.044	3.9	8.5
Bone meal, steamed	30.14	14.53	0.18	0.46	...	0.22	0.61	0.084	13.8	7.4
Bone meal, steamed, solvent	32.11	14.23	...	...	...	0.22	0.64	0.096	25.9	8.3
Brewers' grains, dried	0.29	0.48	0.10	0.26	0.18	0.31	0.14	0.025	17.1	9.7
Buckwheat	0.09	0.31	0.45	...	...	...	.....	0.004	15.4	4.3
Buttermilk	0.14	0.08	0.07	0.10	0.04	0.01	0.06	....	....	....
Buttermilk, condensed	0.44	0.26	0.23	0.31	0.12	0.03	0.19	....	....	....
Buttermilk, dried	1.40	0.98	0.71	0.95	0.36	0.08	0.48	....	1.6	....
Citrus pulp, dried	2.04	0.15	0.62	...	...	...	0.16	0.016	3.1	2.6
Citrus seed meal	1.00	0.64	1.31	...	...	...	0.60	0.029	3.4	3.0
Coconut oil meal, exp. or hydr. process	0.21	0.64	1.95	0.04	...	0.34	0.36	0.068	34.3	4.3
Coconut oil meal, solv. proc.	0.17	0.61	...	...	0.03	...	.....	....	....	....
Corn, dent, from National Research Council nationwide survey, good corn year.										
Corn, dent, Grade No. 1	0.02	0.28	0.29	0.01	0.04	0.12	0.10	0.002	2.5	1.9

TABLE IV. Mineral matter content—*continued.*

Feeding stuff	Calcium	Phosphorus	Potassium	Sodium	Chlorine	Sulfur	Magnesium	Iron	Manganese	Copper
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Mg. per lb.	Mg. per lb.
Concentrates—Cont.										
Corn, dent, Grade No. 2 . . .	0.02	0.27	0.29	0.01	0.04	0.12	0.10	0.002	2.4	1.8
Corn, dent, Grade No. 3 . . .	0.02	0.27	0.28	0.01	0.04	0.12	0.10	0.002	2.4	1.8
Corn, dent, from National Research Council nation-wide survey, in year with much soft corn.										
Corn, dent, Grade No. 2 . . .	0.02	0.26	0.28	0.01	0.05	. . .	0.11	0.002	2.2	0.7
Corn, dent, Grade No. 3 . . .	0.02	0.26	0.28	0.01	0.04	. . .	0.11	0.002	2.2	0.7
Corn, dent, Grade No. 4 . . .	0.02	0.25	0.27	0.01	0.04	. . .	0.11	0.002	2.1	0.7
Corn, dent, Grade No. 5 . . .	0.02	0.24	0.26	0.01	0.04	. . .	0.10	0.002	2.0	0.7
Corn ears, includ. kernels & cobs (corn-and-cob meal)	0.04	0.22	0.40	. . .	. . .	. . .	. . . . .	. . . .	. . . . .	. . . .
Corn bran	0.04	0.14	0.56	. . .	0.05	0.08	0.26	. . . .	7.3	. . . .
Corn feed meal	0.03	0.34	0.28	0.10	. . .	0.11	0.19	. . . .	2.2	. . . .
Corn gluten feed	0.41	0.80	0.54	0.95	0.22	0.22	0.29	0.046	10.8	21.7
Corn gluten meal	0.14	0.41	0.02	0.10	0.07	. . .	0.05	0.040	3.3	12.8
Corn meal, degerminated . .	0.01	0.14	. . .	. . .	. . .	. . .	. . . . .	0.002	. . . .	0.4
Corn oil meal, exp. or hydr. .	0.06	0.56	0.13	. . .	0.11	. . .	0.28	0.021	5.0	5.3
Corn oil meal, solvent	0.03	0.50	. . .	. . .	. . .	. . .	. . . . .	0.032	7.5	5.9
Cottonseed, whole	0.14	0.68	1.11	0.29	. . .	0.24	0.32	0.014	5.5	22.7
Cottonseed, whole-pressed .	0.17	0.64	1.25	. . .	. . .	. . .	0.36	. . . .	. . . .	. . . .
Cottonseed feed, below 36% protein	0.26	0.83	1.22	0.06	0.02	0.26	0.49	. . . .	. . . .	. . . .
Cottonseed meal or cake, 45% protein or more . . .	0.23	1.12	. . .	. . .	. . .	. . .	0.55	0.018	9.3	11.1
Cottonseed meal or cake, 43% protein grade, not including Texas analyses .	0.23	1.07	1.45	. . .	. . .	0.48	0.62	0.097	. . . .	. . . .
Cottonseed meal or cake, 41% protein grade, not including Texas analyses .	0.20	1.11	1.48	0.07	0.05	0.40	0.52	0.016	10.4	8.4
Cottonseed meal, 41% protein grade, solvent process	. . . .	1.19	1.47	0.05	0.04	0.21	0.58	0.015	9.1	9.7
Cowpea seed	0.10	0.46	1.30	0.27	0.04	0.25	0.26	0.036	18.2	2.0
Crab meal	15.15	1.63	0.45	1.03	1.52	0.32	0.88	0.436	60.8	14.9
Distillers dried corn grains, without solubles	0.11	0.48	0.24	0.10	0.05	0.47	0.08	0.024	11.8	20.5
Distillers dried corn grains, with solubles	0.16	0.74	0.65	0.36	0.17	0.30	0.25	0.031	12.9	28.0
Distillers dried rye grains . .	0.13	0.43	0.04	0.17	0.05	0.44	0.17	. . . .	8.4	. . . .
Distillers dried corn solubles	0.33	1.39	1.74	0.24	0.26	0.37	0.64	0.055	33.4	37.6
Fish meal, herring	2.97	2.08	. . .	. . .	1.06	. . .	. . . . .	. . . .	4.5	. . . .
Fish meal, menhaden	5.30	2.81	. . .	. . .	0.32	. . .	. . . . .	0.056	11.7	3.8
Fish meal, salmon	5.49	3.65	. . .	. . .	. . .	. . .	. . . . .	0.018	3.6	5.4
Fish meal, sardine	4.41	2.57	0.33	0.18	0.41	. . .	0.10	0.030	10.1	9.2
Fish meal, white fish	6.76	3.69	. . .	. . .	. . .	. . .	. . . . .	. . . .	6.5	. . . .
Fish solubles, condensed . .	0.17	0.82	. . .	2.13	2.62	0.12	0.02	0.003	7.6	18.9
Flaxseed	0.22	0.52	0.79	. . .	. . .	0.23	0.40	0.009	27.7	. . . .
Hominy feed, 5% fat or more	0.05	0.57	0.61	0.13	. . .	0.03	0.23	0.008	6.9	5.5
Kafir grain	0.03	0.31	0.34	0.06	0.10	0.16	0.15	0.001	7.4	3.0
Kelp, dried	2.48	0.28	. . .	. . .	. . .	. . .	0.85	. . . .	. . . .	. . . .
Linseed meal, exp. or hydr. process, all analyses	0.37	0.86	1.24	0.11	0.04	0.38	0.58	0.017	17.9	12.0
Linseed meal, exp. or hydr., 37% protein grade	0.39	0.86	1.10	0.06	0.04	0.42	0.60	. . . .	. . . .	. . . .
Linseed meal, solvent process, 36% protein grade . .	0.40	0.83	1.38	0.14	0.04	. . .	0.60	0.033	17.1	11.7

TABLE IV. Mineral matter content—*continued.*

Feeding stuff	Calcium	Phosphorus	Potassium	Sodium	Chlorine	Sulfur	Magnesium	Iron	Manganese	Copper
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Mg. per lb.	Mg. per lb.
Concentrates—Cont.										
Linseed meal, exp. or hydr., 34% protein guarantee ..	0.41	0.85	1.14	0.15	0.04	0.40	0.52	0.024	19.1	11.8
Linseed meal, exp. or hydr., 32% protein guarantee ..	0.32	0.88	1.40	0.07	0.04	0.36	0.54	0.012	17.4	11.8
Liver meal, animal	0.62	1.27	...	...	...	...	.....	0.063	4.0	40.5
Malt, barley	0.08	0.47	0.43	0.08	...	...	0.18	0.006	8.4	2.5
Malt sprouts	0.26	0.79	0.21	1.36	0.36	0.80	0.18	....	14.4	....
Meat scrap, or dry-rendered tankage, 55% pro. grade	8.49	4.18	0.55	1.68	1.31	0.50	0.27	0.044	4.3	4.4
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade	10.67	5.27	1.46	0.73	0.75	...	1.13	0.050	5.6	0.7
Milk, cows	0.12	0.10	0.14	0.05	0.20	...	.....	....	....	0.02
Millet seed, hog, or proso ..	0.05	0.30	0.43	...	...	...	0.16	....	....	....
Milo grain	0.03	0.28	0.35	0.01	0.08	...	0.13	0.004	6.0	7.3
Molasses, beet	0.05	0.02	4.77	1.17	1.27	0.48	0.23	0.005	2.1	8.0
Molasses, beet, Steffen's proc.	0.11	0.02	4.66	0.92	1.99	0.44	0.01	....	....	....
Molasses, cane, or blackstrap	0.66	0.08	3.67	0.17	2.75	0.34	0.35	0.019	19.2	....
Molasses, citrus	1.08	0.08	0.09	0.27	0.07	...	0.14	0.034	11.8	33.1
Oat kernels, without hulls (oat groats)	0.08	0.46	0.39	0.05	0.09	0.20	0.15	0.010	13.0	2.9
Oat meal, feeding, or rolled oats	0.07	0.46	0.37	0.14	0.02	0.26	0.16	0.006	18.7	2.4
Oat middlings	0.08	0.45	0.57	...	...	...	.....	0.038	20.0	....
Oat mill by-product	0.18	0.20	0.60	0.04	0.10	0.12	0.08	0.005	..	2.3
Oats, grain	0.09	0.33	0.43	0.09	0.12	0.21	0.16	0.007	19.9	3.8
Palm-kernel oil meal	....	0.69	0.42	...	...	...	.....	0.017	101.6	19.3
Peanut kernels, without hulls	0.06	0.44	0.54	0.56	0.02	0.25	0.18	....	....	....
Peanut oil meal, exp. or hydr.	0.16	0.54	1.15	0.42	0.03	0.18	0.24	....	....	....
Pineapple bran, or pulp, dried	0.28	0.08	...	...	...	...	.....	0.054	....	....
Potato meal, or dried potatoes	0.07	0.20	1.97	...	0.36	...	.....	....	1.3	....
Rice, brown	0.04	0.25	...	...	0.08	...	.....	0.001	9.2	1.2
Rice bran	0.08	1.36	1.74	...	0.07	0.18	0.95	0.019	189.9	5.9
Rice grain, or rough rice ..	0.08	0.32	0.34	...	0.09	...	0.14	....	....	....
Rice polishings, or rice polish	0.05	1.18	1.17	0.11	0.13	0.17	0.65	....	....	....
Rye grain	0.10	0.33	0.47	0.04	0.02	0.16	0.12	0.008	37.0	3.4
Rye feed	0.08	0.69	0.83	...	...	0.04	0.23	....	....	....
Skimmilk, centrifugal	0.13	0.10	0.15	...	...	0.03	0.01	0.0005	0.1	0.5
Skimmilk, dried	1.28	1.04	1.46	...	...	0.32	0.12	0.005	1.0	5.2
Sorghum gluten feed	0.09	0.59	1.45	...	...	...	0.44	....	22.0	....
Sorghum gluten meal	0.02	0.17	0.50	...	...	...	0.16	....	7.3	....
Soybean seed	0.25	0.59	1.50	0.22	0.03	0.22	0.28	0.008	13.4	7.1
Soybean oil meal, exp. or hydr., all analyses	0.27	0.63	1.77	0.24	0.07	0.33	0.25	0.016	14.7	8.2
Soybean oil meal, solv., all an.	0.29	0.64	1.92	0.34	...	0.43	0.27	0.013	12.5	6.5
Sunflower seed	0.17	0.52	0.66	...	...	...	.....	0.003	9.8	....
Sunflower seed, hulled	0.20	0.96	0.92	0.03	0.01	0.02	0.38	....	....	....
Sunflower-seed oil meal, from well-hulled seed	0.26	1.22	1.08	...	0.19	...	.....	....	10.4	....
Tankage, or meat meal, digester proc., 60% prot. gr.	6.37	3.23	0.46	1.67	1.75	0.70	0.70	0.213	8.7	17.6
Tankage, or meat meal, digester proc., 55% prot. gr.	7.33	3.93	...	...	...	...	.....	0.152	3.2	9.1
Velvet bean seeds and pods (velvet bean feed)	0.24	0.38	1.20	0.14	0.22	0.15	0.21	0.013	....	....
Wheat grain, aver. of all types	0.04	0.39	0.42	0.06	0.08	0.20	0.14	0.006	19.9	3.7
Wheat bran, all analyses ...	0.13	1.29	1.23	0.06	0.04	0.22	0.59	0.017	52.6	5.3

TABLE IV. Mineral matter content—*continued*.

Feeding stuff	Calcium	Phosphorus	Potassium	Sodium	Chlorine	Sulfur	Magnesium	Iron	Manganese	Copper
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Mg. per lb.	Mg. per lb.
Concentrates—Cont.										
Wheat flour middlings	0.09	0.71	0.89	0.07	0.04	0.20	0.32	....	....	....
Wheat germ meal	0.08	1.11	0.29	0.71	0.07	0.32	0.34	0.011	72.5	4.3
Wheat mixed feed	0.11	1.09	1.28	0.22	...	...	0.51	0.010	46.7	8.5
Wheat red dog	0.07	0.51	0.60	0.66	0.14	0.26	0.29	0.006	17.1	2.9
Wheat standard middlings ..	0.09	0.93	1.04	0.22	0.03	0.23	0.37	0.010	53.8	10.0
Whey, from cheddar cheese	0.05	0.04	0.19	...	...	...	.....	0.002	0.1	....
Whey, dried	0.86	0.72	...	...	...	1.04	.....	0.021	2.4	23.9
Yeast, brewers' dried	0.13	1.56	1.72	0.07	...	0.38	0.23	0.013	2.6	15.0
Yeast, torula, dried	0.57	1.68	1.88	0.01	...	...	0.13	0.009	5.8	6.1
Farm Animals										
(*not including contents of digestive tract*)										
Beef calf, at birth	1.25	0.68	0.22	0.21	0.16	0.17	0.05	0.02	....	....
Beef calf, wt. 250 lbs.	1.36	0.80	0.24	0.20	0.13	0.16	0.04	0.02	....	....
Beef calf, wt. 450 lbs.	1.11	0.65	0.22	0.18	0.12	0.15	0.04	0.01	....	....
Beef steer, fat, wt. 1,110 lbs.	1.47	0.79	0.20	0.16	0.11	0.14	0.04	0.02	....	....
Beef steer, very fat, wt. 1,850 lbs.	0.94	0.51	0.12	0.10	0.07	0.10	0.03	0.01	....	....
Lamb, fat	0.92	0.49	0.14	...	...	...	0.03	....	....	....
Sheep, before fattening	0.94	0.52	0.14	...	...	...	0.03	....	....	....
Sheep, fat	0.85	0.45	0.12	...	...	...	0.03	....	....	....
Pig, before fattening	0.77	0.46	0.16	...	...	...	0.03	....	....	....
Pig, fat	0.45	0.29	0.11	...	...	...	0.02	....	....	....
Wool										
Wool, unwashed	0.13	0.03	4.67	...	...	...	0.02	....	....	....

Tables V. Vitamin Content of Feeding Stuffs

Vitamin content data.—To furnish as complete information as possible concerning the vitamin content of important feeding stuffs, the following compilations of vitamin analyses have been made for this twenty-second edition of *Feeds and Feeding.*

The average values given in these tables must be considered only very approximate, because information on the amounts of vitamins in feeds is still very limited. Also, the amounts of a certain vitamin in various lots of any particular feed may vary widely. (189)

In the various divisions of the tables, a dash (—) indicates that the feed contains none or no significant amount of the vitamin. A star (*) shows that information is not available concerning the content of the vitamin. Where a value is an average of less than 5 analyses, it is printed in italics in Table V, instead of in ordinary type.

The amount of each vitamin is shown in milligrams per pound of feed as fed to livestock, and not on the dry matter basis. The amounts are thus stated (instead of in percentages), because the weights of vitamins in feeds are very small.

Sources of data.—Much of the information in these tables has been obtained from the following sources: The first is the extensive compilation of vitamin analyses by Ellis and Madsen of the United States Department of Agriculture, published in United States Department of Agriculture Mimeographed Circular 61.

The second is the compilation made by the late Frank E. James, executive secretary of the Committee on Feed Composition of the National Research Council, of which the author is a member. The author cooperated in this compilation, by furnishing data which he had compiled. This compilation was published in mimeographed form by the National Research Council in 1947, as a report of the Committee on Feed Composition.

The third is a compilation of analyses of by-product concentrate feeding stuffs, made by Donald E. Miller, technical secretary of the Committee on Feed Composition. This compilation has recently been published in preliminary form by the National Research Council. The author cooperated in this compilation by furnishing data which he had compiled largely from published reports of the state agricultural experiment stations and the United States Department of Agriculture.

Carotene, vitamin A activity, and B-complex vitamins.—The main table (Table V.) shows the approximate content of important feeds in carotene and in certain B-complex vitamins (thiamine, riboflavin, niacin, and pantothenic acid), so far as data are available.

Since the carotene content in feeds of the same name varies so widely, especially in the case of roughages, the following summary by Guilbert of the California Station is very helpful. (National Research Council, Recommended Nutrient Allowances for Beef Cattle, 1945.) This indicates the common range in carotene content in various types of feeds.

Range in carotene content of various types of feeds

	Carotene Mg. per lb.
Fresh green legumes and grasses, immature	15 to 40
Alfalfa meal, dehydrated, fresh, dehydrated without field curing, very bright green color	110 to 135
Alfalfa meal, dehydrated, after considerable time in storage, bright green color	50 to 70
Alfalfa leaf meal, bright green color	60 to 80
Legume hays, including alfalfa, very quickly cured with minimum sun exposure, bright green color, leafy	35 to 40
Legume hays, including alfalfa, good green color, leafy	18 to 27
Legume hays, including alfalfa, partly bleached, moderate amount of green color	9 to 14

Range in carotene content of various types of feeds—continued.

	Carotene Mg. per lb.
Legume hays, including alfalfa, badly bleached or discolored, traces of green color	4 to 8
Nonlegume hays, including timothy, cereal, and prairie hays, well cured, good green color	9 to 14
Nonlegume hays, average quality, bleached, some green color	4 to 8
Legume silage	5 to 20
Corn and sorghum silages, medium to good green color	2 to 10
Grains, mill feeds, protein concentrates, and by-product concentrates, except yellow corn and its by-products	0.01 to 0.2

In addition to the amounts of carotene given in the first column of figures in the main table which follows immediately, the second column states the approximate vitamin A activity, measured in International Units of vitamin A. These values have been computed on the assumption that 0.6 microgram (0.0006 milligram) of carotene is equivalent to 1 International Unit of vitamin. As has been shown previously, this is the approximate relative value of carotene and vitamin A for poultry and for rats. (**193, 1517**) For cattle, sheep, horses, and swine, the relative vitamin A value of carotene is much less than this.

Other B-complex vitamins.—But little information is available concerning the amounts in feeds of the other B-complex vitamins which are not included in the main table. The approximate amounts of biotin, choline, folic acid, and pyridoxine in some important feeds are shown in Table Va. Since betaine can partially replace choline in function, the amounts of betaine in certain feeds are also stated in this table. (**218**)

Table Vb shows the approximate content of vitamin B_{12} in the few feeds in which the content has been determined.

Vitamin D and Vitamin E.—Very little information has been obtained concerning the amounts of these vitamins in various feeds. The available data are given in Tables Vc and Vd. The general information about the content of these vitamins is summarized in Chapter VII. (**204–205, 223**)

TABLE V. Vitamin content of feeding stuffs

Feeding stuff	Carotene	Vitamin A activity	Thiamine	Riboflavin	Niacin	Pantothenic acid
Dry Roughages	Mg. per lb.	I.U. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Alfalfa hay, all analyses	8.2	13,667	1.3	6.2	17.4	8.1
Alfalfa hay, U.S. Grade No. 1	20.3	33,833	1.4	*7.7*	*18.0*	*9.0*
Alfalfa hay, U.S. Grade No. 2	8.5	14,167	*	*	*	*
Alfalfa hay, U.S. Grade No. 3	3.3	5,500	*	*	*	*
Alfalfa hay, barn-dried	12.8	21,333	*	*	*	*
Alfalfa hay, cured in rainy and cloudy weather	2.7	4,500	*	*	*	*
Alfalfa leaf meal, dehydrated	62.9	104,833	2.5	6.9	*18.0*	*15.3*
Alfalfa meal, dehydrated, 20% protein guarantee	54.8	91,333	3.1	7.0	17.3	18.5
Alfalfa meal, dehydrated, 17% protein guarantee	42.4	70,667	1.5	6.1	8.7	12.3
Alfalfa meal, sun-cured, 17% protein guarantee	24.0	40,000	1.1	5.0	16.1	12.7
Alfalfa meal, dehydrated, 15% protein guarantee	28.8	48,000	*	5.0	*	*
Alfalfa meal, dehydrated, 13% protein guarantee	26.0	43,333	*	4.7	*	*
Alfalfa meal, sun-cured, 13% protein guarantee	9.5	15,833	*	4.4	*	*
Alfalfa stem meal	14.0	23,333	*	*	*	*

TABLE V. Vitamin content of feeding stuffs—*continued.*

Feeding stuff	Carotene	Vitamin A activity	Thiamine	Riboflavin	Niacin	Pantothenic acid
	Mg. per lb.	I.U. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Dry Roughages—Cont.						
Alfalfa-bromegrass hay	*6.7*	*11,167*	*	*2.9*	*11.7*	*10.2*
Alfalfa-grass mixed hay	7.7	12,833	*	*	*	*
Alfalfa-grass mixed hay, mostly grass, U.S. Grade No. 1	20.1	33,500	*	*	*	*
Alfalfa-grass mixed hay, mostly grass, U.S. Grade No. 2	*11.9*	*19,833*	*	*	*	*
Alfalfa-grass mixed hay, barn-dried	*17.5*	*29,167*	*	*	*	*
Atlas sorghum stover	*7.7*	*12,833*	*	*	*	*
Bermuda grass hay	20.6	34,333	*	*	*	*
Birdsfoot trefoil hay, before bloom, barn-dried	19.7	32,833	*	*	*	*
Bluegrass hay, Kentucky	*	*	*	*4.5*	*	*
Bluegrass, Kentucky, dehydrated	137.9	229,833	*	*	*	*
Bromegrass hay	*	*	*	*	*17.0*	*
Cereals, young, dehydrated	*135.9*	*226,500*	*2.5*	*7.4*	*29.9*	*4.9*
Clover, Ladino, and grass hay, before bloom, barn-dried	*81.3*	*135,500*	*	*	*	*
Clover, Ladino, and timothy hay	*7.6*	*12,667*	*	*	*	*
Clover, Ladino, & timothy, dehydrated	*65.8*	*109,667*	*	*	*	*
Clover hay, red, all analyses	7.3	12,167	*0.9*	*7.1*	*16.9*	*4.5*
Clover hay, red, U.S. Grade No. 1	11.0	18,333	*	*	*	*
Clover hay, red, U.S. Grade No. 2	*6.3*	*10,500*	*	*	*	*
Clover hay, red, cured in rainy weather	*1.8*	*3,000*	*	*	*	*
Clover and grass hay	6.1	10,167	*	*	*	*
Clover and grass hay, barn-dried	*7.9*	*13,167*	*	*	*	*
Clover and grass hay, second cutting	*13.5*	*22,500*	*	*	*	*
Corn fodder, dry	*1.8*	*3,000*	*	*	*	*
Cottonseed hulls	—	—	*	*1.7*	*	*
Cottonseed hull bran	—	—	0.1	0.7	3.5	*
Grass hay, first cutting	6.2	10,333	*	*	*	*
Grass hay, second cutting	*11.6*	*19,333*	*	*	*	*
Hegari fodder, dry	*2.0*	*3,333*	*	*	*	*
Hegari stover, dry	*1.1*	*1,833*	*	*	*	*
Johnson grass hay	12.9	21,500	*	*	*	*
Kudzu hay	*17.8*	*29,667*	*	*3.4*	*	*
Lespedeza hay, annual	20.4	34,000	*	*4.0*	*	*
Lespedeza hay, sericea	*15.9*	*26,500*	*	*3.9*	*	*
Mixed hay, grasses and legumes, first cutting	6.4	10,667	*	*	*	*
Mixed hay, grasses and legumes, second cutting	*15.3*	*25,500*	*	*	*	*
Mixed hay, grasses and legumes, barn-dried	15.8	26,333	*	*	*	*
Peanut hay	8.0	13,333	*	*4.0*	*	*
Pea vines, from canning factory, dehydrated	*29.7*	*49,500*	*	*13.1*	*	*
Prairie hay, good quality	9.1	15,167	*	*	*	*
Prairie hay, cut very late	*3.6*	*6,000*	*	*	*	*
Red top hay, cut late	1.7	2,833	*	*	*	*
Sorghum fodder, sweet, dry	1.1	1,833	*	*	*	*
Soybean hay, pods forming	*13.6*	*22,667*	*	*	*	*
Soybean hay, late-cut	*3.0*	*5,000*	*	*	*	*
Timothy hay, all analyses	4.4	7,333	*0.6*	*4.1*	*15.5*	*
Timothy hay, U.S. Grade No. 1	9.2	15,333	*	*	*	*
Timothy hay, U.S. Grade No. 2	*4.2*	*7,000*	*	*	*	*
Timothy hay, U.S. Grade No. 3	2.5	4,167	*	*	*	*
Timothy hay, barn-dried	*19.0*	*31,667*	*	*	*	*

TABLE V. Vitamin content of feeding stuffs—*continued.*

Feeding stuff	Carotene	Vitamin A activity	Thia-mine	Ribo-flavin	Niacin	Panto-thenic acid
Green Roughages, Roots, etc.	Mg. per lb.	I.U. per lb	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Alfalfa, green	28.3	47,167	*0.7*	*2.1*	*8.2*	*
Alfalfa and grass	22.2	37,000	*	*	*	*
Apples	*	*	0.2	*0.1*	*2.5*	*
Barley, green	20.9	34,833	*	*	*	*
Bermuda grass, green	38.5	64,167	*	*	*	*
Bluegrass pasture, Kentucky	36.0	60,000	*1.2*	*	*	*
Bluestem, big, green	17.9	29,833	*	*	*	*
Bluestem, mature and weathered	0.6	1,000	*	*	*	*
Bromegrass, smooth, green	31.6	52,667	*	*	*	*
Buffalo grass, mature	12.0	20,000	*	*	*	*
Cabbage	*0.2*	*833*	0.3	0.2	*1.3*	*
Carrots	48.1	80,167	0.3	*0.3*	*6.7*	*0.9*
Clover, crimson, and rye-grass pasture	34.0	56,667	*	*	*	*
Clover, Ladino, green	25.2	42,000	*	*1.8*	*	*
Clover, Ladino, and tall fescue pasture	29.7	49,500	*	*	*	*
Clover, red, green	20.9	34,833	*	*	*9.1*	*
Clover and grass, hay stage	19.2	32,000	*	*	*	*
Corn fodder, green	8.6	14,333	*	*	*	*
Lawn clippings	*43.1*	*71,833*	*	*	*	*
Lovegrass, weeping, young growth	115.3	192,167	*	*	*	*
Mixed legumes and grasses, hay stage	18.1	30,167	*	*	*	*
Oats, green	27.0	45,000	*	*	*	*
Orchard grass, green	*26.6*	*44,333*	*0.8*	*	*	*
Pasture grasses and legumes, northern states, good pasture	*36.0*	*60,000*	*	*1.8*	*18.6*	*
Pasture grasses, western plains, young growth	62.9	104,833	*	*	*	*
Pasture grasses, western plains, summer	40.3	67,167	*	*	*	*
Pasture grasses, western plains, mature	4.9	8,167	*	*	*	*
Pasture grasses, western plains, mature and weathered	2.2	3,667	*	*	*	*
Potatoes	—	—	0.7	0.1	*5.0*	2.9
Rutabagas	*	*	*0.3*	*	*	*
Rye grass, perennial	21.5	35,833	*	*	*	*
Soybean forage	37.8	63,000	*	*	*	*
Sudan grass	21.5	35,833	*	*	*	*
Sweet potatoes	27.2	45,333	*0.4*	0.4	*6.1*	*5.0*
Sweet potatoes, deep yellow, high carotene	62.2	103,667	*	*	*	*
Timothy, green	24.2	40,333	*	*	*	*
Turnips	—	—	0.4	0.2	3.1	0.8
Wheat forage	20.2	33,667	*	*	*	*
Silages						
Alfalfa, not wilted	15.1	25,167	*	*	*	*
Alfalfa, wilted	11.4	19,000	*	*	*	*
Alfalfa-molasses, not wilted	14.5	24,167	*	*	*	*
Alfalfa-phosphoric acid	15.9	26,500	*	*	*	*
Atlas sorghum	3.3	5,500	*	*	*	*
Beet top, sugar	5.1	8,500	*	*	*	*
Clover, Ladino, and grass	15.6	26,000	*	*	*	*
Corn, dent	5.8	9,667	*	*	5.7	*
Grass silage, with small proportion of legumes, not wilted	20.7	34,500	*	*	5.7	*
Grass silage, with small proportion of legumes, wilted	6.2	10,333	*	*	*	*
Legume-grass, mostly legumes	17.1	28,500	*	*	*	*

TABLE V. Vitamin content of feeding stuffs—*continued.*

Feeding stuff	Carotene	Vitamin A activity	Thiamine	Riboflavin	Niacin	Pantothenic acid
	Mg. per lb.	I.U. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Silages—Cont.						
Millet	*8.8*	*14,667*	*	*	*	*
Oats	17.7	29,500	*	*	*	*
Pea-vine, from cannery	21.0	35,000	*	*	*	*
Sorghum, sweet	2.7	4,500	*	*	*	*
Soybean	14.6	24,333	*	*	*	*
Timothy	14.1	23,500	*	*	*	*
Concentrates						
Babassu oil meal	*0.05*	*83*	*	*1.0*	*6.6*	*2.8*
Barley	*0.2*	*333*	2.6	0.6	27.2	3.0
Beans, field, or navy	—	—	2.8	0.8	11.2	*1.4*
Beans, kidney	—	—	2.9	1.0	12.2	*
Beans, lima	—	—	2.0	0.8	9.6	3.8
Beans, mung	—	—	*1.8*	*	*10.4*	*
Beans, pinto	—	—	3.9	1.4	9.9	1.0
Beet pulp, dried	*0.1*	*167*	0.2	0.3	7.4	0.7
Blood flour, or soluble blood meal	—	—	0.2	1.9	13.0	2.4
Blood meal			*	0.7	14.3	0.5
Bone meal, cooked	—	—	*0.1*	*0.6*	*1.9*	*1.0*
Bone meal, steamed	—	—	0.2	0.4	1.9	1.1
Bone meal, steamed, special	—	—	*0.9*	*0.5*	*2.0*	*0.8*
Brewers' dried grains	—	—	0.3	0.7	19.7	3.9
Buckwheat	*	*	2.1	0.7	9.1	5.7
Buttermilk	*	*	*0.2*	*0.7*	*0.6*	*2.1*
Buttermilk, condensed	*7.0*	*1,167*	*	4.8	*	*
Buttermilk, dried	*	*	1.6	14.1	3.9	13.7
Chick peas	*	*	0.8	0.4	17.6	*
Citrus molasses	—	—	*	*2.8*	12.1	*5.7*
Citrus pulp, dried	*0.1*	*167*	0.7	1.1	9.8	5.9
Coconut oil meal, expeller or hydraulic	—	—	*0.4*	*1.6*	*	2.6
Cod-liver oil meal	*	*	*8.2*	15.1	59.9	*20.9*
Corn, dent, from National Research Council nationwide survey, good corn year						
Corn, yellow dent, Grade No. 1	1.3	2,167	1.7	0.5	10.0	2.5
Corn, yellow dent, Grade No. 2	1.3	2,167	1.7	0.5	9.8	2.4
Corn, yellow dent, Grade No. 3	1.3	2,167	1.7	0.5	9.6	2.4
Corn, dent, from National Research Council nationwide survey, in year with much soft corn						
Corn, yellow dent, Grade No. 2	1.3	2,167	1.6	0.6	9.9	3.1
Corn, yellow dent, Grade No. 3	1.3	2,167	1.6	0.6	9.7	3.0
Corn, yellow dent, Grade No. 4	1.2	2,000	1.5	0.6	9.4	3.0
Corn, yellow dent, stored 2 years	1.1	1,833	*	*	*	*
Corn, white dent	—	—	2.2	0.6	7.1	1.7
Corn, pop	*	*	*	0.5	7.8	1.5
Corn, snapped, or ear-corn chops with husks	*	*	*	0.6	*	*
Corn, sweet, mature	*	*	*	*0.8*	*14.6*	*3.7*
Corn bran	*	*	2.2	0.7	19.1	*2.4*
Corn feed meal	*	*	*1.5*	*0.5*	*10.3*	*
Corn germ meal	*	*	*9.0*	1.4	18.5	2.3
Corn gluten feed	3.8	6,333	0.9	1.1	32.7	7.8
Corn gluten meal	7.4	12,333	0.1	0.7	22.7	4.7
Corn meal, degerminated, white	—	—	*0.7*	*0.3*	*4.7*	*1.4*
Corn meal, degerminated, yellow	*	*	*0.3*	*0.2*	*	*

TABLE V. Vitamin content of feeding stuffs—*continued.*

Feeding stuff	Carotene	Vitamin A activity	Thiamine	Riboflavin	Niacin	Pantothenic acid
	Mg. per lb.	I.U. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Concentrates—Cont.						
Corn oil meal, expeller or hydraulic process	*0.2*	*333*	*2.8*	2.4	*21.9*	*1.7*
Corn oil meal, solvent process	—	—	*	*1.7*	*19.1*	*1.5*
Cottonseed meal or cake, hydraulic or expeller process	0.1	167	2.9	2.7	16.3	5.5
Cottonseed meal or cake, solvent process	—	—	*3.7*	*2.1*	*20.7*	*8.1*
Cottonseed, whole pressed	*	*	*	*1.4*	*	*
Cowpea seed	0.1	167	3.7	1.1	12.2	7.0
Crab meal	*	*	*	2.7	*	*3.0*
Distillers dried corn grains, without solubles	*	*	0.7	1.3	12.1	2.6
Distillers dried corn grains, with solubles	1.7	2,833	1.3	3.9	30.4	5.0
Distillers dried rye grains	—	—	0.6	1.5	7.7	2.4
Distillers dried sorghum grains, with solubles	—	—	0.6	2.2	28.6	4.9
Distillers dried wheat grains	0.5	833	0.9	1.7	25.4	3.7
Distillers dried wheat grains, with solubles	1.1	1,833	*	4.8	*34.0*	5.5
Distillers dried corn solubles	*0.3*	*500*	3.1	7.7	52.4	9.5
Distillers dried rye solubles	—	—	1.4	5.8	30.0	13.0
Distillers dried sorghum solubles	—	—	*2.1*	6.8	64.1	12.0
Distillers dried wheat solubles	1.0	1,667	2.3	6.8	87.0	15.3
Fermentation solubles, corn, dried	*	*	*	240.0	*29.4*	*79.7*
Fermentation solubles, dried	—	—	*2.5*	*77.9*	*98.0*	*92.2*
Fish meal	*	*	0.6	3.1	28.8	4.1
Fish meal, herring	*	*	*	4.1	40.4	5.2
Fish meal, menhaden	*	*	0.3	2.2	25.4	*
Fish meal, redfish	*	*	*	3.2	*	*3.8*
Fish meal, salmon	*	*	*0.4*	*2.6*	*11.3*	*3.1*
Fish meal, sardine	*	*	*0.2*	2.7	*28.2*	*4.2*
Fish meal, white fish	*	*	0.8	4.1	31.7	*4.0*
Fish solubles, condensed	0.6	1,000	2.5	6.6	76.7	*16.1*
Fish solubles, condensed, menhaden	*	*	*	*4.3*	*108.4*	*
Fish solubles, condensed, sardine	*	*	*1.8*	7.6	161.4	*18.7*
Fish solubles, dried	*	*	*	*3.5*	*105.5*	*20.4*
Hegari grain	—	—	*	*	*30.8*	*
Hempseed oil meal	—	—	*	*1.3*	*	*1.6*
Hominy feed, white	—	—	4.4	1.0	21.0	3.3
Hominy feed, yellow	*3.1*	*5,167*	3.3	1.1	19.6	3.9
Kafir grain	0.17	283	*	0.6	18.3	*5.7*
Linseed meal, expeller or hydraulic process	0.1	167	2.6	1.5	18.4	5.5
Linseed meal, solvent process	*	*	4.3	*1.3*	*13.7*	*
Liver meal, animal	*	*	0.1	21.0	92.9	20.5
Liver and glandular meal	*	*	*1.2*	18.5	*73.4*	*48.2*
Malt, barley	—	—	1.8	1.3	25.7	3.6
Malt sprouts	—	—	*4.2*	4.7	*26.2*	*
Meat scrap, or dry-rendered tankage, 55% protein grade	—	—	0.1	2.4	25.8	2.2
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade	—	—	*0.5*	2.0	21.7	1.7
Meat and bone scrap, or dry-rendered tankage with bone, 45% protein grade	—	—	*	2.4	16.9	1.1

TABLE V. Vitamin content of feeding stuffs—*continued.*

Feeding stuff	Carotene	Vitamin A activity	Thiamine	Riboflavin	Niacin	Pantothenic acid
	Mg. per lb.	I.U. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Concentrates—Cont.						
Milk, cow's	0.4	667	0.2	0.8	0.8	1.3
Milk, whole, dried	3.2	5,333	1.7	8.9	3.8	10.3
Millet seed, hog, or proso	*	*	3.3	1.7	10.6	*
Milo grain	0.1	167	1.8	0.4	18.3	4.7
Milo head chops	0.3	500	*	0.9	*	*
Molasses, beet	—	—	*	1.1	19.2	2.1
Molasses, cane	—	—	0.4	1.5	15.6	17.4
Molasses, citrus	—	—	*	2.8	12.1	5.7
Oats grain	0.05	83	2.8	0.5	6.3	6.0
Oat kernels, without hulls, (oat groats)	*	*	3.1	0.6	3.7	6.7
Oat meal, feeding, or rolled oats	*	*	3.2	0.8	5.8	5.6
Oat middlings	*	*	3.2	0.8	12.8	10.5
Oat mill by-product (oat mill feed)	0.1	167	*	2.1	*	*
Palm-kernel oil meal	*	*	*	*	20.0	*
Pea seed, field	*	*	1.8	0.8	17.2	4.6
Peanut kernels, without hulls	0.1	167	3.8	1.1	62.3	15.9
Peanut oil meal and hulls, expeller or hydraulic process, 41 to 45% protein	0.1	167	3.1	2.1	78.8	23.5
Peanut oil meal and hulls, solvent, 47% protein	*	*	*	5.0	*	*
Pineapple pulp, or bran, dried	21.7	36,167	*	*	*	*
Rape-seed oil meal	—	—	*	0.9	*	*
Rice, brewers'	—	—	0.64	*	*	*
Rice, brown	—	—	1.1	0.3	17.1	*
Rice, polished	—	—	0.3	0.3	8.1	1.8
Rice bran	—	—	10.2	1.2	137.8	10.7
Rice polishings, or rice polish	—	—	9.4	0.8	241.7	26.5
Rye grain	0.04	67	2.0	0.7	7.1	4.2
Rye middlings	—	—	1.5	1.1	7.7	10.5
Safflower oil meal, from well-hulled seed	*	*	8.2	1.8	10.0	39.0
Sesame oil meal	0.2	333	1.3	1.7	*	2.9
Shrimp meal	*	*	*	1.8	*	*
Skimmilk, centrifugal	—	—	0.2	0.9	0.5	1.6
Skimmilk, dried	—	—	1.6	9.1	5.2	15.3
Sorghum, grain	—	—	2.4	0.6	29.4	4.1
Sorghum seed, sweet	—	—	1.6	*	8.2	*
Soybean seed	0.4	677	5.0	1.2	10.0	7.1
Soybean oil meal, expeller or hydraulic process	0.1	167	1.7	1.6	14.3	6.9
Soybean oil meal, solvent process	0.1	167	3.0	1.5	12.2	6.6
Soybean oil meal, dehulled, solvent, 50% protein guarantee	*	*	1.1	1.4	9.8	*
Starfish meal	*	*	*	4.0	*	*
Sunflower seed	*	*	0.2	1.5	*	*
Sunflower-seed oil meal from partly-hulled seed	*	*	*	1.5	132.4	18.6
Sweet potato meal, or dried sweet potatoes	32.2	53,667	*	*	*	*
Tankage, or meat meal, digester process, 60% protein grade	—	—	0.2	1.1	17.8	1.1
Tankage, or meat meal, digester process, 55% protein grade	—	—	*	0.7	13.1	0.7
Tomato pomace, dried	*	*	5.4	2.8	*	*
Wheat, hard dark red	0.04	67	2.3	0.5	24.1	6.3
Wheat, hard spring	0.04	67	2.3	0.5	28.8	6.4
Wheat, soft	*	*	2.2	0.5	26.8	5.2

TABLE V. Vitamin content of feeding stuffs—*continued.*

Feeding stuff	Carotene	Vitamin A activity	Thiamine	Riboflavin	Niacin	Pantothenic acid
	Mg. per lb.	I.U. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Concentrates—Cont.						
Wheat bran	1.2	2,000	3.6	1.4	95.1	13.2
Wheat brown shorts	*	*	7.8	1.3	40.7	9.4
Wheat brown shorts and screenings	*	*	*	*0.9*	[illegible]	*
Wheat flour, low grade	—	—	*	*0.3*	*11.8*	
Wheat flour middlings, or gray shorts	—	—	7.2	0.9	43.2	8.0
Wheat germ	*	*	12.7	2.3	21.5	5.1
Wheat germ oil meal	*3.0*	*500*	11.5	2.3	23.3	5.6
Wheat red dog, or white shorts	—	—	8.6	0.7	23.9	6.2
Wheat standard middlings	*1.4*	*2,333*	5.8	0.9	44.8	9.0
Whey	—	—	*	*0.6*	*0.4*	*2.4*
Whey, condensed	—	—	*1.4*	9.1	*1.6*	*6.6*
Whey, dried	—	—	1.8	15.9	4.4	18.2
Whey product, dried, with whey fermentation solubles	—	—	*	25.1	*27.1*	*31.2*
Yeast, brewers', dried	—	—	41.7	15.9	203.4	49.9
Yeast, torula, dried	—	—	2.8	20.2	227.4	37.7

TABLE Va. Approximate vitamin content of certain B-complex vitamins

Feeding stuff	Biotin	Choline	Folic acid	Pyridoxine	Betaine
	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg per lb.
Dry Roughages					
Alfalfa hay	0.08	*	*	*	*
Alfalfa leaf meal	0.15	*	*	*	*
Alfalfa meal, dehydrated, 20% protein grade	*	511	*	*	*
Alfalfa meal, dehydrated, 17% protein grade	*	462	3.93	*	1,600
Cereals, young, dehydrated	0.13	*	*	*	*
Clover hay, red	0.04	*	*	*	*
Timothy hay	0.03	*	*	*	*
Green Roughages and Roots					
Cabbage	*	1,139	0.29	*	*
Carrots	*	431	0.29	*	*
Potatoes	*	481	0.64	*	*
Sweet potatoes	*	158	0.30	*	*
Turnips	*	426	0.12	*	*
Concentrates					
Barley feed	*	546	0.35	*	*
Barley grain	0.06	450	0.27	1.6	*
Beans, field, or navy	0.05	*	*	*	*
Beans, lima, mature	*	*	1.50	*	*
Beet pulp, dried	*	377	*	*	*
Beet solubles by-product, condensed	*	*	*	*	68,000
Blood flour	*	127	*	*	*
Blood meal	*	344	*	*	*
Brewers' grains, dried	0.44	720	4.40	0.3	*
Buttermilk, dried	0.13	822	0.18	1.1	*
Cod-liver oil meal	*	*	*	14.9	*
Corn, white dent	0.03	*	*	*	*
Corn, yellow dent	0.03	200	0.14	*	*
Corn bran	0.04	*	*	*	*

TABLE Va. Approximate vitamin content of certain B-complex vitamins.—*continued.*

Feeding stuff	Biotin	Choline	Folic acid	Pyridoxine	Betaine
	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Concentrates—Cont.					
Corn feed meal	*	227	*	*	*
Corn germ meal	*	721	*	*	*
Corn gluten feed	0.15	689	0.14	6.8	*
Corn gluten meal	0.09	150	0.10	3.6	*
Corn oil meal	*	883	*	2.8	*
Cottonseed meal, expeller or hydraulic process	0.50	1,228	*	*	*
Cottonseed meal, solvent process	*	1,301	*	*	*
Distillers dried corn grains, without solubles	0.26	365	*	*	*
Distillers dried corn grains, with solubles	0.30	1,123	*	1.0	*
Distillers dried sorghum grains	0.14	366	*	3.8	*
Distillers dried corn solubles	0.68	2,190	0.51	*	*
Distillers dried sorghum solubles	0.38	*	0.33	*	*
Fermentation solubles, dried	0.41	1,415	2.34	0.8	*
Fish meal	*	1,663	*	6.7	*
Fish meal, herring	*	1,820	*	*	*
Fish meal, redfish	0.07	1,559	*	*	*
Fish meal, salmon	*	1,260	*	*	*
Fish meal, sardine	*	1,345	*	*	*
Fish solubles, condensed	0.07	1,831	*	5.5	*
Fish solubles, condensed, sardine	0.06	1,365	*	*	*
Fish solubles, dried	*	2,374	*	*	*
Hominy feed, white	0.06	*	*	6.0	*
Hominy feed, yellow	0.06	*	0.15	5.4	435
Linseed meal, expeller or hydraulic process	*	746	1.26	*	*
Linseed meal, solvent process	*	557	*	*	*
Liver meal, animal	0.01	5,153	2.52	*	*
Liver and glandular meal	*	4,757	*	*	*
Malt, barley	*	406	*	3.2	*
Meat and bone scrap, or dry-rendered tankage with bone, 50% protein grade	*	909	*	*	*
Molasses, cane	*	398	*	*	*
Oats grain	0.13	435	0.10	*	*
Oat kernels, without hulls, (oat groats)	*	*	*	0.5	*
Oat meal, feeding, or rolled oats	*	505	0.27	*	*
Pea seed, field	0.09	*	*	*	*
Peanut oil meal and hulls, expeller or hydraulic process	*	935	*	*	*
Rice bran	0.19	*	*	*	13.2
Rice polishings or rice polish	0.28	594	*	*	12.6
Safflower oil meal, from well-hulled seed	0.64	1,174	0.20	*	*
Sesame oil meal	*	672	*	*	*
Shrimp meal	*	2,649	*	*	*
Skimmilk, dried	0.15	647	0.28	1.8	*
Soybean seed	0.17	1,300	*	4.9	*
Soybean oil meal, expeller or hydraulic process	0.15	1,185	2.83	*	*
Soybean oil meal, solvent process	*	1,285	0.27	*	*
Soybean oil meal, dehulled, solvent, 50% protein guarantee	*	1,255	*	*	*
Wheat	0.04	458	0.20	*	*
Wheat bran	*	491	0.75	*	*

TABLE Va. Approximate vitamin content of certain B-complex vitamins.—*continued.*

Feeding stuff	Biotin	Choline	Folic acid	Pyridoxine	Betaine
	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.	Mg. per lb.
Concentrates—Cont.					
Wheat flour middlings, or gray shorts	*	447	*	*	*
Wheat germ	*	1,978	0.88	*	*
Wheat germ oil meal	*	1,534	*	*	*
Wheat standard middlings	*	488	0.41	*	*
Whey, dried	*	615	*	1.8	*
Whey product, dried, with whey fermentation solubles	0.17	797	0.40	*	*
Yeast, brewers' dried	0.44	1,766	4.40	19.7	*

TABLE Vb. Vitamin B_{12} content of certain feeding stuffs

It is generally believed that feeds of plant origin have no appreciable amounts of vitamin B_{12} or of other substances having vitamin B_{12} activity.

However, certain feeds of plant origin, including some green forages, dehydrated alfalfa or other dehydrated forage, and some hays, may show an apparent small content of vitamin B_{12} by microbiological methods of analysis.

The approximate vitamin B_{12} contents of certain feeds of animal origin and of certain fermentation by-products are shown in the following table. The amounts of vitamin B_{12}, even in these feeds, are so exceedingly small that the content is stated in terms of micrograms per pound of feed, instead of milligrams. (1,000 micrograms equal 1 milligram.)

Vitamin B_{12} content of certain feeds

Feeding stuff	Vitamin B_{12} per lb. of feed	Feeding stuff	Vitamin B_{12} per lb. of feed
	Micrograms		Micrograms
Buttermilk, dried	9	Fish solubles, cond., redfish	208
Cod-liver oil meal	0.4	Fish solubles, cond., sardine	472
Crab meal	192	Fish solubles, cond., tuna	219
Distillers solubles, dried	13	Liver meal, animal	246
Feather meal, hydrolyzed	39	Meat scrap	31
Fish meal, all analyses	87	Meat and bone scrap	57
Fish meal, herring	107	Milk, cow's	2
Fish meal, menhaden	84	Poultry by-product meal	129
Fish meal, redfish	65	Sewage sludge, dried	817
Fish meal, salmon	41	Skimmilk, dried	25
Fish meal, sardine	85	Whale meat meal	40
Fish meal, tuna	65	Whey, dried	11
Fish meal, white fish	45	Yeast, dried	3
Fish solubles, condensed, all analyses	305	Yeast, molasses distillers, dried	4
Fish solubles, cond., herring	259		

TABLE Vc. Vitamin D content of certain feeding stuffs

Feeding stuff	Vitamin D content in International Units per lb.
Dry Roughages	
Alfalfa hay, field-cured	905
Alfalfa hay, barn-dried	215
Alfalfa, dehydrated	66
Alfalfa leaves, from field-cured hay	4,740
Alfalfa stems, from field-cured hay	780
Clover hay, field-cured	868
Clover hay, barn-dried	195
Mixed grass and legume hay, field-cured	523
Mixed grass and legume hay, barn-dried	448
Mixed grass and legume hay, dehydrated	391
Soybean hay, barn-dried	322
Timothy hay, field-cured	717
Timothy-alfalfa hay, field-cured	613
Timothy-clover hay, field-cured	933
Green Roughages and Silages	
Fresh green forage	Little or none
Alfalfa silage, wilted before ensiling	131
Corn silage	54
Concentrates	
All grains and other seeds and their by-products	None or practically none
Beet pulp, dried	275
Distillers dried corn grains, with solubles	250
Cocoa shells, sun-dried	14,288
Cod-liver oil meal	18,150
Milk, cow's whole milk, in summer	17
Milk, cow's whole milk, in winter	5
Skimmilk, dried	190

TABLE Vd. Vitamin E content of certain feeding stuffs

Feeding stuff	Vitamin E as mg. of alpha-tocopherol per lb. of feed	Feeding stuff	Vitamin E as mg. of alpha-tocopherol per lb. of feed
Dry roughages		**Concentrates**	
Alfalfa hay, field-cured	11.8	Barley grain	5.0
Alfalfa leaf meal	173.8	Corn grain, white	11.2
Bluegrass, Ky., dried	157.0	Corn grain, yellow	11.0
Orchard grass, dried	101.2	Fish meal	95.0
Soybean hay	12.1	Oats grain	16.6
Timothy hay, mixed, U.S. Grade No. 2	5.9	Soybean seed	16.6
		Wheat grain	15.5
Green roughages		Wheat bran	1.4
		Wheat germ	72.0
Alfalfa	69.0	Wheat germ oil	862.0
Bluegrass, Ky.	70.8	Wheat red dog	26.2
Clover, white	45.4	Wheat shorts	14.4
Orchard grass	49.4		
Soybean forage	31.8		

TABLE VI. WEIGHTS OF CONCENTRATES AND OTHER FEEDS

In computing rations for farm animals it is desirable to know the weight per quart, or the bulk, of the different concentrates. The following table, compiled chiefly from *Massachusetts Bulletin 136* by Smith and Perkins, *Louisiana Bulletin 114* by Halligan, and *Indiana Bulletin 141* by Jones, Haworth, Cutler, and Summers is therefore presented.

Feeding stuff	One quart weighs	One pound measures	Feeding stuff	One quart weighs	One pound measures
Concentrates	Lbs.	Qts.	**Concentrates—Cont.**	Lbs.	Qts.
Barley, whole	1.5	0.7	Molasses feeds	0.8	1.3
Barley, ground	1.1	0.9	Oats	1.0	1.0
Beans, field	1.7	0.6	Oats, ground	0.7	1.4
Beet pulp, dried	0.6	1.7	Oatmeal, without hulls	1.7	0.6
Brewers' grains, dried	0.6	1.7	Oat middlings	1.5	0.7
Buckwheat, whole	1.4	0.7	Oat mill feed	0.8	1.3
Buckwheat feed	0.6	1.7	Peas, field	2.1	0.5
Buckwheat flour	1.6	0.6	Rice bran	0.8	1.3
Buckwheat middlings	0.9	1.1	Rice polish	1.2	0.8
Citrus pulp, ground	1.0	1.0	Rye, whole	1.7	0.6
Coconut oil meal	1.5	0.7	Rye, ground	1.5	0.7
Corn, dent, whole	1.7	0.6	Rye bran	0.8	1.3
Corn, dent, ground	1.5	0.7	Rye feed	1.3	0.8
Corn-and-cob meal	1.4	0.7	Rye middlings	1.6	0.6
Corn bran	0.5	2.0	Soybeans	1.8	0.6
Corn germ meal	1.4	0.7	Sunflower seed	1.5	0.7
Corn gluten feed	1.3	0.8	Tankage	1.6	0.6
Corn gluten meal	1.7	0.6	Wheat, whole	1.9	0.5
Cottonseed, whole	0.8	1.3	Wheat, ground	1.7	0.6
Cottonseed meal	1.5	0.7	Wheat bran	0.5	2.0
Cowpeas	1.7	0.6	Wheat mixed feed	0.6	1.7
Distillers' corn grains, dried	0.6	1.7	Wheat flour middlings	1.2	0.8
Flaxseed	1.6	0.6	Wheat screenings	1.0	1.0
Flaxseed screenings	1.1	0.9	Wheat standard middlings	0.8	1.3
Hominy feed	1.1	0.9			
Linseed meal, old process	1.1	0.9	**Roughages**		
Linseed meal, new process	0.9	1.1	Alfalfa meal	0.6	1.7
Malt sprouts	0.6	1.7	Buckwheat hulls	0.5	2.0
Millet seed, foxtail	1.6	0.6	Cottonseed hulls	0.3	3.3
Molasses, cane	3.0	0.3	Oat hulls	0.4	2.5

Table VII. Example Rations for Farm Animals

Using the example rations.—The following examples of balanced rations for the different classes of stock are presented as guides in selecting efficient balanced rations adapted to various conditions. In using these suggestions, one should not limit his choice to the particular combinations of feeds here given. Instead, he should determine whether or not modifications can be made in these rations which will make them more economical under his local conditions. One can readily find which of various available feeds are actually the cheapest by using the method explained in Chapter XII.

Unless otherwise indicated, the amounts of feed shown in the tables are the amounts to be fed per head daily. For animals of different sizes than stated in the tables, the amounts of feed should be increased or decreased in accordance with the amounts of nutrients recommended in Appendix Table III for animals of the particular size.

Making changes in the rations.—The following will indicate the changes that may be made in these rations:

Other grains can be substituted for the grains included in an example ration. If the grain substituted is higher or lower in protein than the grain which it replaces, the amount of protein supplement in the ration should be changed to provide approximately the same percentage of protein in the ration.

For example, ground corn can be replaced by hominy feed, corn feed meal, ground grain sorghum, ground barley, or ground wheat. When barley or wheat is fed in place of corn, the amount of protein supplement may be reduced somewhat. Also, a little less supplement is needed with grain sorghums than with corn.

Where oats are included in a concentrate mixture to provide bulk, they can be replaced by dried beet pulp. More protein supplement will then be needed because of the lower protein content of dried beet pulp.

Instead of the protein supplements used in the various example rations, other supplements can be substituted, such as brewers' dried grains, distillers dried grains, corn gluten meal, and peanut oil meal. If the percentage of protein differs appreciably from that in the supplement used in the example ration, the amount should be changed accordingly. In making any substitution of protein supplements in a ration for swine or poultry, one must be sure that the ration will furnish protein of proper quality. (**1385–1386, 1500–1501**)

The proportions of protein supplements in the example rations are based on the most common grades of the various supplements. For example, the computations have been based on cottonseed meal of 41 per cent protein grade; linseed meal, expeller or hydraulic process, 34 per cent protein guarantee; and soybean oil meal, solvent process, 44 per cent protein guarantee. If the protein supplement used has a decidedly higher or lower protein content than stated, the amount of supplement needed will be altered correspondingly.

Dairy Cattle

Concentrate or "grain" mixtures for dairy cows and heifers

A. Mixtures containing approximately 12 per cent protein

For cows in milk which are fed good alfalfa, soybean, or cowpea hay (at least 1 lb. daily per 100 lbs. live weight) with corn silage, sorghum silage, corn fodder, sorghum, fodder, or roots. When alfalfa, soybean, or cowpea hay is fed as the only roughage, merely a mixture of farm grain supplies sufficient protein for all except unusually high-producing cows.

For cows in milk which are fed red clover hay as the only roughage.

For cows in milk which are on excellent pasture.

For dry cows, when at least one-third the roughage (on the dry basis) is legumes. Other mixtures for fitting dry cows are given in **Division B.**

For heifers over 6 months old, when

one-half the roughage (on the dry basis) is alfalfa, soybean, or cowpea hay.

1. Ground corn	1,160 lbs.
Ground oats	500 lbs.
Wheat bran	220 lbs.
Soybean oil meal (or cottonseed meal)	100 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 9.8%
Total dig. nutrients, 75.3%

2. Ground corn	1,130 lbs.
Ground oats	500 lbs.
Wheat bran	200 lbs.
Linseed meal	150 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 9.8%
Total dig. nutrients, 75.1%

3. Ground barley (or wheat)	1,030 lbs.
Ground oats	700 lbs.
Wheat bran	250 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 10.1%
Total dig. nutrients, 72.91%

4. Ground corn	1,000 lbs.
Ground oats	640 lbs.
Wheat bran	200 lbs.
Corn gluten feed	70 lbs.
Soybean oil meal	70 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 9.8%
Total dig. nutrients, 74.5%

5. Ground grain sorghum	1,400 lbs.
Ground oats	330 lbs.
Wheat bran	200 lbs.
Cottonseed meal (or soybean oil meal)	50 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 9.6%
Total dig. nutrients, 76.0%

6. Corn-and-cob meal	1,310 lbs.
Wheat bran	500 lbs.
Cottonseed meal (or soybean oil meal)	85 lbs.
Linseed meal	85 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 9.6%
Total dig. nutrients, 70.9%

B. Mixtures for fitting dry cows and for freshening cows

Mixture No. 1, which contains somewhat more than 12 per cent total protein, is suitable for use when at least one-third of the roughage, on the dry basis, is legume forage. When little or no legume roughage is available, such a mixture as No. 2, which contains 16 per cent protein, is preferable.

1. Ground corn	760 lbs.
Ground oats	600 lbs.
Wheat bran	500 lbs.
Linseed meal	100 lbs.
Bone meal (or other safe supplement)	20 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 10.2%
Total dig. nutrients, 72.0%

2. Ground corn	590 lbs.
Ground oats	500 lbs.
Wheat bran	500 lbs.
Linseed meal	360 lbs.
Bone meal (or other safe supplement)	20 lbs.
Ground limestone	10 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 13.1%
Total dig. nutrients, 71.4%

C. Mixtures containing approximately 14 per cent protein

For cows in milk which are fed red clover hay (at least 1 lb. daily per 100 lbs. live weight) and corn or sorghum silage or corn or sorghum fodder, when protein supplements are expensive.

For cows in milk which are on very good pasture.

For dry cows when only one-fourth of the roughage (on the dry basis) is legume.

For heifers over 6 months old, when one-half the roughage (on the dry basis) is clover hay.

1. Ground corn	1,055 lbs.
Ground oats	500 lbs.
Wheat bran	200 lbs.
Soybean oil meal (or cottonseed meal)	225 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 11.9%
Total dig. nutrients, 75.3%

2. Ground corn .... 980 lbs.
Ground oats .... 500 lbs.
Wheat bran .... 200 lbs.
Linseed meal .... 300 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 11.5%
Total dig. nutrients, 74.8%

3. Ground barley .... 1,090 lbs.
Ground oats .... 600 lbs.
Wheat bran .... 200 lbs.
Soybean oil meal (or cottonseed meal) .... 90 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 11.5%
Total dig. nutrients, 73.6%

4. Ground corn .... 955 lbs.
Ground oats .... 500 lbs.
Wheat bran .... 225 lbs.
Corn gluten feed .... 150 lbs.
Soybean oil meal .... 150 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 11.8%
Total dig. nutrients, 74.7%

5. Ground grain sorghum ...... 1,275 lbs.
Ground oats .... 330 lbs.
Wheat bran .... 200 lbs.
Cottonseed meal (or soybean oil meal) .... 175 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 11.1%
Total dig. nutrients, 75.5%

6. Corn-and-cob meal .... 1,220 lbs.
Wheat bran .... 450 lbs.
Cottonseed meal (or soybean oil meal) .... 155 lbs.
Linseed meal .... 155 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 11.2%
Total dig. nutrients, 71.1%

D. Mixtures containing approximately 16 per cent protein

For cows in milk which are fed good red clover or alsike clover hay (at least 1 lb. daily per 100 lbs. live weight) with corn silage, sorghum silage, corn fodder, sorghum fodder, or roots.

For cows in milk which are fed good mixed clover-and-grass hay (containing at least 30 per cent clover) and corn or sorghum silage or corn or sorghum fodder, when protein supplements are unusually expensive.

For cows in milk which are on good pasture.

For dry cows which are fed little or no legume roughage.

1. Ground corn .... 945 lbs.
Ground oats .... 500 lbs.
Wheat bran .... 200 lbs.
Soybean oil meal (or cottonseed meal) .... 335 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 13.9%
Total dig. nutrients, 75.1%

2. Ground barley .... 1,000 lbs.
Ground oats .... 560 lbs.
Wheat bran .... 200 lbs.
Soybean oil meal (or cottonseed meal) .... 220 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 13.6%
Total dig. nutrients, 73.8%

3. Ground corn .... 830 lbs.
Ground oats .... 500 lbs.
Wheat bran .... 200 lbs.
Corn gluten feed .... 225 lbs.
Soybean oil meal (or cottonseed meal) .... 225 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 13.6%
Total dig. nutrients, 74.6%

4. Ground corn .... 820 lbs.
Ground oats .... 500 lbs.
Wheat bran .... 220 lbs.
Linseed meal .... 440 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 13.3%
Total dig. nutrients, 74.3%

5. Ground grain sorghum ...... 1,180 lbs.
Ground oats .... 300 lbs.
Wheat bran .... 200 lbs.
Cottonseed meal (or soybean oil meal) .... 300 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 12.7%
Total dig. nutrients, 75.1%

6. Corn-and-cob meal .... 1,090 lbs.
Wheat bran .... 450 lbs.
Cottonseed meal (or soybean oil meal) .... 220 lbs.
Linseed meal .... 220 lbs.
Salt .... 20 lbs.
Total .... 2,000 lbs.
Dig. protein, 13.0%
Total dig. nutrients, 71.1%

E. Mixtures containing approximately 18 per cent protein

For cows in milk which are fed mixed clover-and-timothy hay or other mixed clover-and-grass hay containing at least 30 per cent clover (at least 1 lb. of hay daily per 100 lbs. live weight), this hay being fed with corn or sorghum silage, corn or sorghum fodder, or roots.

For cows in milk which are on fair pasture.

For heifers over 6 months old, when only about one-fourth the roughage (on the dry basis) is legume.

1. Ground corn	685 lbs.
Ground oats	500 lbs.
Wheat bran	200 lbs.
Soybean oil meal	270 lbs.
Distillers dried corn grains	325 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 14.7%
Total dig. nutrients, 75.8%

2. Ground barley	940 lbs.
Ground oats	500 lbs.
Wheat bran	200 lbs.
Soybean oil meal (or cottonseed meal)	340 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 15.5%
Total dig. nutrients, 74.0%

3. Ground corn	680 lbs.
Ground oats	500 lbs.
Wheat bran	200 lbs.
Corn gluten feed	300 lbs.
Soybean oil meal (or cottonseed meal)	300 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 15.5%
Total dig. nutrients, 74.3%

4. Ground corn	540 lbs.
Ground oats	500 lbs.
Wheat bran	200 lbs.
Linseed meal	370 lbs.
Corn gluten feed	370 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 15.1%
Total dig. nutrients, 73.5%

5. Ground grain sorghum	1,045 lbs.
Ground oats	300 lbs.
Wheat bran	200 lbs.
Cottonseed meal (or soybean oil meal)	435 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 14.4%
Total dig. nutrients, 74.5%

6. Corn-and-cob meal	970 lbs.
Wheat bran	450 lbs.
Cottonseed meal (or soybean oil meal)	280 lbs.
Linseed meal	280 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 14.5%
Total dig. nutrients, 71.1%

F. Mixtures containing approximately 20 per cent protein (Add 20 lbs. ground limestone per ton if roughage is grown on soil very deficient in calcium.)

For cows in milk which are fed mixed legume-and-grass hay containing less than 30 per cent legumes, this hay being fed with corn or sorghum silage, corn or sorghum fodder, or roots.

For cows in milk which are fed non-legume roughage of good quality and which are producing sufficient milk so that they require at least 8 to 10 lbs. of concentrate or grain mixture.

For cows in milk which are on poor pasture.

For heifers over 6 months old which are fed no legume roughage.

1. Ground corn	630 lbs.
Ground oats	400 lbs.
Wheat bran	200 lbs.
Soybean oil meal	370 lbs.
Distillers dried corn grains	380 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 16.7%
Total dig. nutrients, 76.4%

2. Ground corn	510 lbs.
Ground oats	300 lbs.
Wheat bran	200 lbs.
Linseed meal	470 lbs.
Corn gluten feed	500 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 16.9%
Total dig. nutrients, 73.9%

3. Ground barley	915 lbs.
Ground oats	400 lbs.
Wheat bran	200 lbs.
Soybean oil meal (or cottonseed meal)	465 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 17.6%
Total dig. nutrients, 74.4%

4. Ground corn	430 lbs.
Ground oats	300 lbs.
Wheat bran	200 lbs.
Corn gluten feed	450 lbs.
Soybean oil meal	400 lbs.
Cane molasses	200 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 17.4%
Total dig. nutrients, 72.1%

5. Ground grain sorghum	900 lbs.
Ground oats	300 lbs.
Wheat bran	200 lbs.
Cottonseed meal (or soybean oil meal)	580 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 16.2%
Total dig. nutrients, 74.0%

6. Corn-and-cob meal	870 lbs.
Wheat bran	400 lbs.
Cottonseed meal (or soybean oil meal)	355 lbs.
Linseed meal	355 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 16.3%
Total dig. nutrients, 71.3%

G. Mixtures containing approximately 24 per cent protein (Add 20 lbs. of ground limestone per ton if roughage is grown on soil very deficient in calcium.)

For cows in milk which are fed good-quality non-legume roughage and which are not producing sufficient milk to require so much as 8 lbs. of concentrate or grain mixture.

For cows in milk which are fed only non-legume roughage of fair to poor quality.

1. Ground corn	380 lbs.
Ground oats	300 lbs.
Wheat bran	200 lbs.
Soybean oil meal (or cottonseed meal)	500 lbs.
Distillers dried corn grains	600 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 20.2%
Total dig. nutrients, 77.1%

2. Ground barley	580 lbs.
Ground oats	400 lbs.
Wheat bran	200 lbs.
Soybean oil meal (or cottonseed meal)	500 lbs.
Linseed meal	300 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 21.2%
Total dig. nutrients, 74.1%

3. Ground corn	220 lbs.
Ground oats	200 lbs.
Wheat bran	200 lbs.
Corn gluten feed	600 lbs.
Soybean oil meal (or cottonseed meal)	560 lbs.
Cane molasses	200 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 21.2%
Total dig. nutrients, 72.0%

4. Ground corn	380 lbs.
Ground oats	200 lbs.
Wheat bran	200 lbs.
Linseed meal	500 lbs.
Corn gluten feed	500 lbs.
Soybean oil meal	200 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 20.7%
Total dig. nutrients, 74.1%

5. Ground grain sorghum	680 lbs.
Ground oats	300 lbs.
Wheat bran	200 lbs.
Cottonseed meal	500 lbs.
Soybean oil meal	300 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 20.2%
Total dig. nutrients, 74.0%

6. Corn-and-cob meal	620 lbs.
Wheat bran	400 lbs.
Cottonseed meal (or soybean oil meal)	500 lbs.
Linseed meal	460 lbs.
Salt	20 lbs.
Total	2,000 lbs.

Dig. protein, 19.7%
Total dig. nutrients, 71.3%

Beef Cattle

Wintering mature beef breeding cows in calf, weight 1,000 lbs.

1. Legume hay or mixed legume-and-grass hay of good quality, 16 to 25 lbs.
2. Legume hay, 5 to 10 lbs.; cereal straw, 10 to 15 lbs.
3. Corn silage or sorghum silage, 50 to 60 lbs.; cottonseed meal, soybean oil meal, linseed meal, or other high-protein supplement, 1 lb.; ground limestone, 0.1 lb.
4. Corn silage or sorghum silage, 25 to 40 lbs.; legume hay, 5 to 7 lbs.
5. Cereal straw, full-fed; linseed meal, cottonseed meal, soybean oil meal, or other high-protein supplement, 1 lb.; ground limestone, 0.1 lb.
6. Prairie hay or other grass hay, full-fed (16 to 25 lbs.); plus 0.5 to 0.75 lb. high-protein supplement unless hay is early-cut. It is advisable to add 0.1 lb. ground limestone if hay is grown on soil deficient in calcium.

Wintering beef calves to gain 0.75 to 1.00 lb. per head daily

If a gain of much more than 1.00 lb. per head daily is desired, it will usually be necessary to add 2 lbs. or more of grain to these rations.

1. Legume hay or mixed hay containing at least one-half legumes, 12 to 15 lbs.
2. Corn silage or sorghum silage, 25 to 35 lbs.; soybean oil meal, cottonseed meal, linseed meal, or other high-protein supplement, 1 lb.; ground limestone, 0.1 lb. unless silage is raised on soil well supplied with calcium.
3. Corn silage or sorghum silage, 20 to 30 lbs.; legume hay, 3 to 4 lbs.
4. Prairie hay, other grass hay, or corn or sorghum fodder, 10 to 14 lbs.; cottonseed meal, soybean oil meal, or other high-protein supplement, 0.75 to 1.00 lb.; ground limestone, 0.1 lb. unless roughage is raised on soil well supplied with calcium.
5. Prairie hay, other grass hay, or corn or sorghum fodder, 8 to 12 lbs.; ground barley, oats, grain sorghum, or wheat, 2 lbs.; ground limestone, 0.1 lb. unless roughage is raised on soil well supplied with calcium.

Wintering beef yearlings

In general the same types of rations are satisfactory as have been suggested for wintering beef calves, except that greater amounts of feed are required and some of the roughage may consist of such cheap feeds as corn or sorghum stover, or cereal straw.

Calves being fattened for baby beef, average weight 600 lbs.

1. Corn or sorghum silage, 10 lbs. or more; alfalfa or other legume hay, 2 lbs. or more; corn or ground grain sorghum, 10 lbs.; soybean oil meal, linseed meal, cottonseed meal, or other high-protein supplement, 1.25 to 1.5 lbs.
2. Alfalfa, soybean, or cowpea hay, 4 to 5 lbs.; corn or grain sorghum, 11 lbs.; cottonseed meal, linseed meal, or other high-protein supplement, 0.50 to 0.75 lb. If 6 lbs. or more of legume hay of good quality are fed, no protein supplement is needed.
3. Alfalfa, soybean, or cowpea hay, 4 to 5 lbs.; ground barley, wheat, or oats, 12 lbs.
4. Red clover hay, 4 to 5 lbs.; corn or ground grain sorghum, 11 lbs.; soybean oil meal, linseed meal, cottonseed meal, or other high-protein supplement, 1.0 to 1.25 lbs.
5. Clover-and-timothy hay (containing 30 per cent or more clover), 4 to 5 lbs.; corn or ground grain sorghum, 11 lbs.; cottonseed meal, soybean oil meal, or other high-protein supplement, 1.5 lbs.
6. Corn or sorghum silage, 16 lbs.; corn or ground grain sorghum, 10 lbs.; cottonseed meal, soybean oil meal, linseed meal, or other high-protein supplement, 1.5 to 2 lbs.; ground limestone, 0.1 lb.
7. Cottonseed hulls, 4 lbs.; cowpea hay, 2 lbs.; corn or ground grain sorghum, 10 lbs.; cottonseed meal or other high-protein supplement, 1.5 lbs.

Fattening yearling cattle, average weight 900 lbs.

1. Corn or sorghum silage, 15 lbs.; alfalfa or other legume hay, 3 lbs.; corn or ground grain sorghum, 13 lbs.; linseed meal, cottonseed meal, or other high-protein supplement, 1 lb.
2. Alfalfa, soybean, or cowpea hay, 6 to 8 lbs.; corn or other grain, 14 lbs.
3. Red clover hay, 6 to 8 lbs.; corn or ground grain sorghum, 13.5 lbs.; cottonseed meal, soybean oil meal, or other high-protein supplement, 0.5 lb.
4. Red clover hay, 6 to 8 lbs.; ground barley, wheat, or oats, 14 lbs.
5. Clover-and-timothy hay (containing 30 per cent or more clover), 6 to 8 lbs.; corn or ground grain sorghum, 13 lbs.; soybean oil meal, linseed meal, cottonseed meal, or other high-protein supplement, 1 to 1.25 lbs.
6. Corn or sorghum silage, 20 lbs.; corn or ground grain sorghum, 13 lbs.; high-protein supplement, 1.5 to 1.75 lbs.; ground limestone, 0.1 lb.
7. Cottonseed hulls, 6 lbs.; cowpea hay, 2 lbs. or more; corn or ground grain sorghum, 13 lbs.; cottonseed meal or other high-protein supplement, 1.5 lbs.

Fattening 2-year-old cattle, weight 1,000 lbs.

1. Corn or sorghum silage, 25 lbs.; alfalfa, soybean, or cowpea hay, 4 lbs.; corn or ground grain sorghum, 14 lbs. Adding 0.5 lb. high-protein supplement will increase the rate of gain slightly and may be profitable. The supplement should be added if less legume is fed.
2. Corn or sorghum silage, 25 lbs.; red clover hay, 4 lbs.; corn or ground grain sorghum, 14 lbs.; linseed meal, cottonseed meal, or other high-protein supplement, 1.0 lb.
3. Alfalfa, soybean, or cowpea hay, 10 lbs.; corn or other grain, 15 lbs.
4. Red clover hay, 10 lbs.; corn or ground grain sorghum, 14.5 lbs.; cottonseed meal or other high-protein supplement, 0.5 lb.
5. Clover-and-timothy hay (containing 30 per cent or more clover), 10 lbs.; corn or ground grain sorghum, 14 lbs.; soybean oil meal or other high-protein supplement, 1.0 lb.
6. Corn or sorghum silage, 30 lbs.; corn or ground grain sorghum, 14 lbs.; linseed meal or other high-protein supplement, 1.5 lbs.; ground limestone, 0.1 lb.
7. Cottonseed hulls, 7 lbs.; cowpea hay, 3 lbs.; corn or ground grain sorghum, 14 lbs.; cottonseed meal or other high-protein supplement, 1.5 lbs.

Sheep

Wintering pregnant ewes up to 4 to 6 weeks before lambing, weight 120 lbs.

1. Good-quality legume hay or mixed legume-and-grass hay containing 50 per cent legumes, 3.6 to 4.5 lbs.
2. Legume hay, 2.6 to 3.3 lbs.; corn or sorghum silage, 2.0 to 3.0 lbs.
3. Corn fodder, sorghum fodder, corn stover, sorghum stover, or cereal straw, full-fed (1.0 to 2.0 lbs.); legume hay, 2.0 lbs. It may be necessary to add 0.25 to 0.50 lb. grain to this ration to keep the ewes in the desired condition.
4. Roots, 2.0 to 3.0 lbs.; legume hay, 3.1 to 3.6 lbs.
5. Early-cut, well-cured grass hay, 1.8 to 2.3 lbs.; legume hay, 1.8 to 2.3 lbs.
6. Early-cut grass hay, 2.3 to 3.0 lbs.; corn or sorghum silage, 2.0 to 3.0 lbs.; 0.25 lb. linseed meal or other high-protein supplement; 0.25 ounce ground limestone per head daily.

Wintering pregnant ewes during 4 to 6 weeks before lambing

To one of the preceding roughage allowances, add 0.5 lb. per head daily (or more if necessary) of one of the concentrate mixtures listed later.

Ewes not on pasture nursing lambs

To one of the preceding roughage allowances, add 1.0 lb. or slightly more of one of the following concentrate mixtures:

Concentrate or grain mixtures for ewes

These concentrate mixtures are suitable for ewes which are nursing lambs or for pregnant ewes.

A. For feeding when at least one-half the roughage (on the dry basis) is actually good legume roughage.

1. Oats, 67 lbs.; wheat bran, 33 lbs.
2. Corn or other grain, 50 lbs.; oats, 20 lbs.; wheat bran, 20 lbs.; linseed meal, 10 lbs.
3. Corn, 80 lbs.; linseed meal, 20 lbs.
4. Oats, 50 lbs.; corn, 50 lbs. This mixture is slightly too low in protein to use for ewes nursing lambs unless nearly all of the roughage is legume forage.
5. A good mixed dairy feed containing 12 to 14 per cent total protein.

B. For feeding when only a small part or none of the roughage is legume

(When fed such roughage, ewes nursing lambs should receive 1.25 lbs. per head daily of concentrate mixture.)

1. Oats, 30 lbs.; corn or other grain, 20 lbs.; wheat bran, 30 lbs.; linseed meal or other high-protein supplement, 20 lbs.
2. Oats, 60 lbs.; wheat bran, 25 lbs.; linseed meal or other high-protein supplement, 15 lbs.
3. A good mixed dairy feed containing 16 to 18 per cent total protein.

Fattening lambs on full feed, weight 70 lbs.

1. Legume hay, 1.4 lbs.; corn or grain sorghum, 1.5 lbs. The addition of 0.1 lb. high-protein supplement will increase the gains a trifle, but will usually not be profitable.
2. Legume hay, 1.4 lbs.; barley, wheat, or oats, 1.5 lbs.
3. Corn or sorghum silage, 1.75 lbs.; legume hay, 0.75 lb.; corn or other grain, 1.5 lbs.; linseed meal, cottonseed meal, or other high-protein supplement, 0.10 lb. Lambs will make satisfactory gains without the supplement, if at least this much good legume hay is fed. However, unless supplements are unusually high in price, it will generally pay to add the supplement.
4. Corn or sorghum silage, 3.0 to 4.0 lbs.; corn or other grain, 1.5 lbs.; cottonseed meal, linseed meal, soybean oil meal, or other high-protein supplement, 0.20 to 0.30 lb.; ground limestone, 0.25 ounce.
5. Mixed clover-and-grass hay, 1.4 lbs.; corn, 1.5 lbs.; linseed meal, 0.10 to 0.15 lb.
6. Cottonseed hulls, 1.0 lb.; cowpea hay, 0.50 lb.; corn or other grain, 1.5 lbs.; cottonseed meal or other high-protein supplement, 0.15 to 0.20 lb.

Horses and Mules

Horses and mules at hard work, weight 1,200 lbs.

1. Grass hay, 12 lbs.; oats, 16 lbs.
2. Grass hay, 12 lbs.; corn, 13 lbs.; linseed meal or other high-protein supplement, 1 lb.
3. Legume hay, 12 lbs.; corn, 13.5 lbs.
4. Legume hay, 6 lbs.; grass hay, 6 lbs.; corn, 14 lbs.
5. Shredded corn fodder, 6 lbs.; legume hay, 6 lbs.; oats, 15 lbs.
6. Oats or barley straw, chopped, 4 lbs.; legume hay, 8 lbs.; oats, 16 lbs.

Horses and mules at medium work, weight 1,200 lbs.

1. Grass hay, 14 lbs.; oats, 11 lbs.
2. Grass hay, 14 lbs.; corn, 9 lbs.; linseed meal or other high-protein supplement, 0.75 lb.
3. Legume hay, 14 lbs.; corn, 9 lbs.
4. Legume hay, 7 lbs.; grass hay, 7 lbs.; corn, 9.5 lbs.
5. Shredded corn fodder, 7 lbs.; legume hay, 7 lbs.; oats, 10 lbs.
6. Oat or barley straw, chopped, 5 lbs.; legume hay, 9 lbs.; oats, 11 lbs.

Horses and mules at light work, weight 1,200 lbs.

1. Grass hay, 16 lbs.; oats, 6 lbs.
2. Grass hay, 16 lbs.; corn, 4.5 lbs.; linseed meal or other high-protein supplement, 0.5 lb.
3. Legume hay, 16 lbs.; corn, 4 lbs.
4. Legume hay, 8 lbs.; grass hay, 8 lbs.; corn, 4.5 lbs.
5. Shredded corn fodder, 8 lbs.; legume hay, 8 lbs.; oats, 5 lbs.
6. Oat or barley straw, chopped, 6 lbs.; legume hay, 10 lbs.; oats, 6 lbs.

Idle horses and mules, live weight 1,200 lbs.

1. Grass hay, 17.5 lbs.; linseed meal or other high-protein supplement, 0.75 lb.
2. Legume hay, 17 lbs.
3. Legume hay, 9 lbs.; grass hay, 9 lbs.
4. Corn or sorghum stover, 11 lbs.; legume hay, 8 lbs.
5. Corn or sorghum silage, 15 lbs.; oat or barley straw, 6 lbs.; legume hay, 7 lbs.
6. Oat or barley straw, 6 lbs.; legume hay, 12 lbs.

Brood mares nursing foals, but not at work, live weight 1,200 lbs.

1. Alfalfa, soybean, or cowpea hay, 16 lbs.; corn or other grain, 6 lbs.
2. Red clover hay, 16 lbs.; oats or ground barley, 3 lbs.; corn, 3 lbs.
3. Mixed clover-and-timothy hay (containing 30 per cent or more clover), 16 lbs.; oats, 6 lbs.
4. Timothy or other grass hay, 16 lbs.; oats, 3 lbs.; bran, 3 lbs.; linseed meal or other high-protein supplement, 1 lb.

Swine

Except where indicated, the amounts of feed stated are the amounts in each 100 lbs. of concentrate mixture, and not the amounts eaten per head daily.

Salt should be supplied, free-choice, in addition to these rations, or else 0.5 lb. of salt should be added to each 100 lbs. of the feed mixture. In areas where there is likelihood of a trace-mineral deficiency, trace-mineralized salt should be used instead of ordinary salt, or a mineral supplement containing trace minerals should be provided, free-choice.

Brood sows, gilts, and boars

An excellent ration for pregnant brood sows and gilts is merely sufficient corn or other grain, with choice legume hay fed in a rack, and either 0.25 to 0.35 lb. per head daily of tankage, meat scraps, or fish meal, or else 4 to 5 lbs. skimmilk or buttermilk per head daily.

The following mixtures are also excellent for brood sows, gilts, and boars. The first of the following tables gives mixtures which are well adapted for feeding in dry lot, without pasture, to pregnant gilts, to suckling sows of all ages, and to boars.

The second table gives mixtures for feeding in dry lot, without pasture, to pregnant sows which are a year or more old. Such sows need less protein than pregnant gilts or than sows which are nursing litters.

If desired, the proportion of legume hay in a mixture for pregnant sows and for boars may be increased to 20 lbs. per 100 lbs. of mixture. On the other hand, for sows that are nursing litters, it may be wise to reduce the proportion of legume hay to 5 or 10 lbs. per 100 lbs. of mixture.

The third table gives in separate divisions suitable mixtures for feeding on good pasture to pregnant gilts and then mixtures for feeding to pregnant sows that are a year old or older.

Mixtures for pregnant gilts and suckling sows of all ages—not on pasture

	1	2	3	4	5	6	7	8
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Ground corn or grain sorghum	75	59	52	69	72	..	..	..
Ground barley or wheat	..	..	..	..	..	81	79	77
Ground oats	..	..	25	..	..	..	..	..
Wheat middlings	..	20	..	..	..	..	..	..
Tankage, meat scrap, or fish meal	10	6	8	..	4	4	2	..
Soybean oil meal	..	..	..	15	9	..	4	7
Legume hay	15	15	15	15	15	15	15	15
Phosphorus supplement	..	..	..	0.4	..	..	..	0.4
Ground limestone	..	..	..	0.6	..	..	..	0.6
Total	100	100	100	100	100	100	100	100

Mixtures for pregnant yearling and older sows—not on pasture

	1	2	3	4	5	6	7
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Ground corn or grain sorghum	77	61	54	72	75	..	..
Ground barley or wheat	..	..	..	..	..	82	80
Ground oats	..	..	25	..	..	..	..
Wheat middlings	..	20	..	..	..	..	..
Tankage, meat scrap, or fish meal	8	4	6	..	3	2	..
Soybean oil meal	..	..	..	12	7	..	4
Legume hay	15	15	15	15	15	15	15
Phosphorus supplement	..	..	..	0.4	..	0.4	0.4
Ground limestone	..	..	..	0.6	..	0.6	0.6
Total	100	100	100	100	100	100	100

Pregnant gilts and older sows on good pasture

	Pregnant gilts				Older pregnant sows			
	1	2	3	4	1	2	3	4
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Ground corn or grain sorghum	93	75	70	..	95	78	71.5	..
Ground barley or wheat	..	..	..	79.5	..	..	..	99.5
Ground oats	..	..	25	..	..	..	25	..
Wheat middlings	..	20	..	20	..	20	..	..
Tankage, meat scrap, or fish meal	7	..	5	..	5	..	3.5	..
Soybean oil meal	..	5	..	..	..	2	..	..
Phosphorus supplement	..	..	..	0.5	..	..	..	0.5
Total	100	100	100	100	100	100	100	100

Pig pre-starters for early-weaned pigs

1. Rolled oats or oat groats, 1,050 lbs.; molasses, 200 lbs.; sugar, 200 lbs.; soybean oil meal, 400 lbs.; dried skimmilk, 100 lbs.; phosphorus supplement, 20 lbs.; ground limestone, 20 lbs.; trace-mineralized salt, or salt plus a trace-mineral mixture, 10 lbs.; plus vitamin and antibiotic pre-mix, supplying vitamins A, D, riboflavin, niacin, calcium pantothenate, choline, vitamin B_{12}, and an effective antibiotic; total 2,000 lbs. (Ill. Cir. 719.)
2. Yellow corn, fine-ground, 235 lbs.; sugar, cane or beet, 200 lbs.; dextrose (corn sugar), 100 lbs.; oat groats, finely-ground, 100 lbs.; dried skimmilk, spray-dried, low heat, 800 lbs.; dried whey, 200 lbs.; soybean oil meal, solvent, 50% protein, re-ground fine, 100 lbs.; stabilized lard, 100 lbs.; condensed fish solubles, 50 lbs.; dicalcium phosphate, 11 lbs.; calcium carbonate, 3 lbs.; iodized salt, 10 lbs.; trace-mineral mixture, 4 lbs.; corn steep water, dried, 20 lbs.; brewers' dried yeast, 20 lbs.; dried beet pulp, 40 lbs.; vitamin, antibiotic, and arsonic supplement pre-mix, 7 lbs., supplying the vitamins stated in the preceding formula and also niacin, thiamine, pantothenic acid, choline, pyridoxine, folic acid, para-amino-benzoic acid, ascorbic acid, vitamin E, and vi-

tamin K, 7 lbs.; total, 2,000 lbs. (Iowa Station, mimeo. rpt.)

3. Yellow corn, fine-ground, 300 lbs.; sugar, cane or beet, 300 lbs.; dextrose (corn sugar), 100 lbs.; oat groats, finely-ground, 100 lbs.; dried whey, 300 lbs.; soybean oil meal, solvent, 50% protein, re-ground fine, 600 lbs.; stabilized lard, 100 lbs.; condensed fish solubles, 50 lbs.; dicalcium phosphate, 34 lbs.; calcium carbonate, 9 lbs.; iodized salt, 10 lbs.; trace-mineral mixture, 4 lbs.; corn steep water, dried, 20.5 lbs.; brewers' dried yeast, 20 lbs.; dried beet pulp, 40 lbs.; methionine, 0.5 lb.; vitamin, antibiotic, and arsonic supplement premix as in preceding formula, 7 lbs.; pepsin (proteolytic enzyme, 1:3,000), 5 lbs.; total, 2,000 lbs. (Iowa Station, mimeo. rpt.)

Pig starters, or mixtures for creep-feeding suckling pigs

1. For pigs on good pasture a simple ration is excellent, such as self-fed, free-choice, yellow corn (coarsely ground or shelled) or else hulled oats or rolled oats, or a mixture of corn and oats, with one of the protein supplemental mixtures advised in Chapter XXXIV for pasture feeding, also self-fed free-choice. (**1422**)
2. For pigs in dry lot. Ground yellow corn, 80 lbs.; soybean oil meal, 12 lbs.; fish meal, 1 lb.; meat scrap, 3 lbs.; dehydrated alfalfa meal, 2–4 lbs.; mineral mixture (equal parts phosphorus supplement, ground limestone, and trace-mineralized salt), 1.5 lbs.; antibiotic-vitamin B_{12} feed supplement, 0.5 lb.; vitamin A-D supplement, 0.1 lb.
3. For pigs in dry lot. Ground yellow corn, 46 lbs.; ground oat groats, 30 lbs.; soybean oil meal, 18 lbs.; dried skimmilk, 5 lbs.; plus vitamin, antibiotic, and mineral supplements as in preceding ration.
4. For pigs in dry lot. Ground yellow corn, ground grain sorghum, or ground wheat, 34 lbs.; rolled oats or ground oat groats, 30 lbs.; soybean oil meal, 5.5 lbs.; meat scrap, 5 lbs.; fish meal, 5 lbs.; dried skimmilk, 10 lbs.; sugar, cane or glucose, 10 lbs.; iodized salt, 0.5 lb.; plus vitamin and antibiotic supplements.

Growing and fattening pigs

In addition to these rations, salt should be supplied in a suitable mineral box or feeder, or 0.5 lb. of salt should be mixed with each 100 lbs. of the entire ration. Also, except where a phosphorus supplement or ground limestone is included in the mixture, it is advisable to provide a suitable calcium-phosphorus mineral mixture separately.

An antibiotic-vitamin B_{12} feed supplement should be added to rations for growing and fattening pigs not on excellent pasture.

Where a mixture of grain and protein supplements is fed, the grain should be ground. Legume hay should be ground or chopped very finely for use in a feed mixture.

In these rations other plant-protein supplements can be substituted for soybean oil meal or linseed meal, when used as advised in the discussions of the various supplements in Part II. Another plant-protein supplement should be substituted for all or part of the soybean oil meal only when the quality of protein in the ration will still be satisfactory.

A. Supplemental mixtures for self-feeding, free-choice, to pigs not on pasture, in addition to corn or grain sorghum, also self-fed, free-choice

As is stated in Chapter XXXVI, when such supplemental mixtures are self-fed, free-choice, with barley, wheat, oats, or rye, which are all higher in protein than corn or grain sorghum, the pigs may eat more of the supplement than they need. To prevent waste of the expensive supplement, the proper amount of supplemental mixture may be hand-fed, or the desired proportion of the supplemental mixture may be mixed with ground grain, and the mixture self-fed. (**1391**)

1. The trio mixture or modifications of it. See Articles **1418–1420** for discussions of the trio mixture and modifications which can be made in it. The original trio mixture contained 50 lbs. tankage, meat scrap, or fish meal; 25 lbs. good-quality alfalfa or other legume hay; and 25 lbs. linseed meal, soybean oil meal, cottonseed meal, or other high-protein supplement of plant origin. When tankage, meat scrap, and fish meal are high in price or limited in supply, the propor-

tion of animal-protein supplement may be reduced, as in the following mixtures. Also, if the pigs are well started on good pasture before being placed in dry lot, the proportion of legume hay may be reduced, as in supplemental mixture No. 4.

2. Tankage, meat scrap, or fish meal, 40 lbs.; legume hay, 25 lbs.; soybean oil meal, 20 lbs.; linseed meal, peanut oil meal, or cottonseed meal, 14 lbs.; salt, 1 lb.
3. Tankage, meat scrap, or fish meal, 20 lbs.; legume hay, 25 lbs.; soybean oil meal, 30 lbs.; linseed meal, cottonseed meal or peanut oil meal, 20 lbs.; ground limestone, 3 lbs.; salt, 2 lbs.
4. Tankage or meat scrap, 20 lbs.; fish meal, 20 lbs.; soybean oil meal, 40 lbs.; cottonseed meal, 10 lbs.; alfalfa leaf meal, 10 lbs.

B. Supplemental mixtures for self-feeding, free-choice, to pigs on good pasture, in addition to corn or grain sorghum, also self-fed, free-choice

1. One-half tankage, meat scrap, or fish meal, and one-half soybean oil meal, cottonseed meal, linseed meal, or other high-protein supplement of plant origin.
2. Tankage, meat scrap, or fish meal, 40 lbs.; soybean oil meal, 40 lbs.; linseed meal, cottonseed meal, or peanut oil meal, 19 lbs.; salt, 1 lb.
3. Tankage, meat scrap, or fish meal, 20 lbs.; soybean oil meal, 50 lbs.; linseed meal, cottonseed meal, or peanut oil meal, 24 lbs.; ground limestone, 4 lbs.; salt, 2 lbs.

C. Other rations for growing and fattening pigs not on pasture

1. Corn or grain sorghum, self-fed; skimmilk or buttermilk, 6 lbs. per head daily; choice alfalfa hay fed in rack.
2. Barley or wheat, self-fed; skimmilk or buttermilk, 4 to 5 lbs. per head daily; choice alfalfa hay fed in rack.
3. Corn or grain sorghum, self-fed; tankage, meat scrap, or fish meal, self-fed, free-choice; choice alfalfa hay fed in rack.

D. Other rations for growing and fattening pigs on good pasture

1. Corn or grain sorghum, self-fed; skimmilk or buttermilk, 3 to 4 lbs. per head daily.
2. Barley or wheat, self-fed; skimmilk or buttermilk, 2 to 3 lbs. per head daily.
3. Corn or grain sorghum, self-fed; tankage, meat scrap, or fish meal, self-fed, free-choice.

E. Mixtures for self-feeding or hand-feeding to growing and fattening pigs of various weights, which are in dry lot, without pasture

Any of the following mixtures are well suited for feeding to growing and fattening pigs which are in dry lot, without pasture. It will be noted that the proportion of protein supplements steadily decreases as the pigs become older.

Mixtures for growing and fattening pigs in dry lot

		Weaning to 50 lbs.	50 to 75 lbs.	75 to 125 lbs.	125 to 175 lbs.	Over 175 lbs.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1.	Corn	72	77	82	84	87
	Tankage, meat scrap, or fish meal	8	8	6	5	4
	Soybean oil meal	15	10	7	6	4
	Legume meal or hay	5	5	5	5	5
	Total	100	100	100	100	100
2.	Corn	60	65	74	76	78
	Wheat flour middlings	15	15	..	..	..
	Wheat standard middlings	..	..	10	10	10
	Tankage, meat scrap, or fish meal	6	5	5	4	3
	Soybean oil meal	14	10	6	5	3.5
	Legume meal or hay	5	5	5	5	5
	Phosphorus supplement	..	..	..	..	0.5
	Total	100	100	100	100	100

Mixtures for growing and fattening pigs in dry lot—*continued.*

	Weaning to 50 lbs.	50 to 75 lbs.	75 to 125 lbs.	125 to 175 lbs.	Over 175 lbs.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3. Corn	55	61	72	74	77
Wheat flour middlings	15	15	..	..	..
Wheat standard middlings	..	..	10	10	10
Tankage, meat scrap, or fish meal	6	5	5	4	3
Linseed meal	19	14	8	7	5
Legume meal or hay	5	5	5	5	5
Total	100	100	100	100	100
4. Corn	58	63	64	66	68
Oats	15	15	20	20	20
Tankage, meat scrap, or fish meal	8	6	5	4	3
Soybean oil meal	14	11	6	5	4
Legume meal or hay	5	5	5	5	5
Total	100	100	100	100	100
5. Barley	72	81	86	89	90
Tankage, meat scrap, or fish meal	6	5	4	2	2
Linseed meal	17	9	5	3	2
Legume meal or hay	5	5	5	5	5
Phosphorus supplement	..	..	..	0.5	0.5
Ground limestone	..	..	..	0.5	0.5
Total	100	100	100	100	100
6. Grain sorghum	76	81	85	88	89
Tankage, meat scrap, or fish meal	7	6	4	2	2
Soybean oil meal	12	8	6	4	3
Legume meal or hay	5	5	5	5	5
Phosphorus supplement	..	..	..	0.5	0.5
Ground limestone	..	..	..	0.5	0.5
Total	100	100	100	100	100

F. Mixtures for self-feeding or hand-feeding to growing and fattening pigs of various weights, which are on good pasture

Mixtures for growing and fattening pigs on good pasture

	Weaning to 50 lbs.	50 to 75 lbs.	75 to 125 lbs.	125 to 175 lbs.	Over 175 lbs.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1. Corn	82	87	89	92	93
Tankage, meat scrap, or fish meal	7	5	4	4	3
Soybean oil meal	11	8	7	4	3.5
Phosphorus supplement	..	..	..	..	0.5
Total	100	100	100	100	100
2. Corn	70	75	77	84	85
Wheat flour middlings	15	15	..	..	..
Wheat standard middlings	..	..	15	10	10
Tankage, meat scrap, or fish meal	5	4	3	3	2
Soybean oil meal	10	6	5	3	2
Ground limestone	..	..	..	..	1
Total	100	100	100	100	100
3. Corn	68	73	75	81	84
Oats	15	15	15	10	10
Tankage, meat scrap, or fish meal	7	5	4	3	2
Soybean oil meal	10	7	6	5	3
Bone meal	..	..	..	0.5	0.5
Ground limestone	..	..	..	0.5	0.5
Total	100	100	100	100	100

Mixture for growing and fattening pigs on good pasture—*continued.*

		Weaning to 50 lbs.	50 to 75 lbs.	75 to 125 lbs.	125 to 175 lbs.	Over 175 lbs.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
4.	Barley	85	91	93	99	99
	Tankage, meat scrap, or fish meal	5	4	3	..	..
	Linseed meal	10	5	3	..	..
	Phosphorus supplement	..	..	0.5	0.5	0.5
	Ground limestone	..	..	0.5	0.5	0.5
	Total	100	100	100	100	100
5.	Grain sorghum	86	91	94	95	95
	Tankage, meat scrap, or fish meal	6	4	3	2	2
	Soybean oil meal	8	5	3	2	2
	Phosphorus supplement	..	..	..	0.5	0.5
	Ground limestone	..	..	..	0.5	0.5
	Total	100	100	100	100	100

POULTRY

Formula patterns for mashes for chickens

The following tables, based on present information concerning the nutrient requirements of chickens, show desirable formula patterns for mashes for various classes of chickens. (Hill, Norris, Scott, and Heuser, New York, Cornell Feed Service No. 48.)

Recommended formula patterns for all-mash poultry rations

Ingredients	Starter	Confinement grower	Layer	Breeder
	Lbs. per ton	Lbs. per ton	Lbs. per ton	Lbs. per ton
High-energy grain products (corn, wheat, wheat red dog, milo, oat meal)	800+	700+	900+	900+
Medium- and low-energy grain products (oats, barley, wheat flour middlings, wheat standard middlings, wheat bran)	0–400	0–600	0–500	0–500
Vegetable protein supplements (soybean oil meal, corn gluten meal, peanut oil meal)	400–600	350–450	250–350	200–300
Animal protein supplements, minimum levels (fish meal, fish solubles, meat scrap)	50–100	30– 80	—	50–100
Other B-vitamin carriers (dried milk products, dried yeast, distillers dried solubles, fermentation solubles)	50–100	30–100	—	50–100
Dehydrated alfalfa meal	50–100	50–100	50–100	50–100
Additional riboflavin, vitamin B_{12}, calcium pantothenate, niacin and vitamin A when needed *	+	+	+	+
Vitamin D_3 (feeding oils or D-activated animal sterols)	+	+	+	+
Calcium and phosphorus supplements (steamed bone meal, dicalcium phosphate, defluorinated phosphate, limestone)	30– 50	40– 60	100–120	100–120
Salt	5	5	10	10
Manganese sulfate (70% feeding grade)	0.4	0.4	0.4	0.4
Antibiotic feed supplement	+	?	—	—

* Refers to the use of supplements of riboflavin, calcium pantothenate, niacin, vitamin B_{12} and vitamin A sources of guaranteed vitamin content, or other vitamin-rich feedstuffs when the formula is otherwise deficient in any of these nutrients.

Recommended formula patterns for poultry mashes fed with grain

Ingredients	Growers: Confinement	Growers: Pasture	Layer	Breeder
	Lbs. per ton	Lbs. per ton	Lbs. per ton	Lbs. per ton
High-energy grain products (corn, wheat, wheat red dog, milo, oat meal)	600+	500+	600+	600+
Medium- and low-energy grain products (oats, barley, wheat flour middlings, wheat standard middlings, wheat bran)	0–600	0–800	0–600	0–600
Vegetable protein supplement (soybean oil meal, corn gluten meal, peanut oil meal)	450–550	400–500	500–700	400–500
Animal protein supplements; minimum levels (fish meal, fish solubles, meat scrap)	50–100	–	–	100–150
Other B-vitamin carriers (dried milk products, dried yeast, distillers dried solubles, fermentation solubles)	50–100	–	–	100–150
Dehydrated alfalfa meal	100	–	100–150	100–150
Additional riboflavin, vitamin B_{12}, calcium pantothenate, niacin and vitamin A when needed *	+	–	+	+
Vitamin D_3 (feeding oils or D-activated animal sterols)	+	–	+	+
Calcium and phosphorus supplements (steamed bone meal, dicalcium phosphate, defluorinated phosphate, limestone)	70– 90	80–100	90–120	80–100
Salt	10	20	20	20
Manganese sulfate (70% feeding grade)	0.5	0.5	0.5	0.5
Antibiotic feed supplement	+	?	–	–

* Refers to the use of supplements of riboflavin, calcium pantothenate, niacin, vitamin B_{12} and vitamin A sources of guaranteed vitamin content, or other vitamin-rich feedstuffs when the formula is otherwise deficient in any of these nutrients.

Laying hens and laying pullets

In addition to the mash and scratch grain in these rations, oyster shell or another source of calcium should be available at all times in hoppers. Plenty of fresh water should also be furnished.

Where alfalfa meal is used as a source of vitamin A (carotene), the recommendations are based on alfalfa meal containing 100,000 International Units of vitamin A potency per pound. If alfalfa meal of unknown or low content of vitamin A value is used, additional vitamin A supplementation will be necessary.

A. Laying mashes with which an equal weight of grain is fed

1. Ground yellow corn, 795 lbs.; ground wheat, 300 lbs.; soybean oil meal, 540 lbs.; fish meal, 50 lbs.; meat and bone scrap, 50 lbs.; distillers dried corn solubles, 50 lbs.; alfalfa meal (high-quality), 100 lbs.; dicalcium phosphate, 60 lbs.; ground limestone, 40 lbs.; iodized salt, 15 lbs.; manganese sulfate (70%), 0.5 lb.; riboflavin, 1,500 milligrams; vitamin A, 2,000,000 I.U. (in addition to the high-quality alfalfa meal); vitamin D, 1,360,000 I.C.U.; total, 2,000.5 lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.)
2. Ground barley, 200 lbs.; ground yellow corn, 400 lbs.; ground milo, 200 lbs.; ground wheat, 200 lbs.; wheat bran, 300 lbs.; fish meal, 158 lbs.; meat and bone scrap, 50 lbs.; soybean oil meal, 250 lbs.; dried whey, 50 lbs.; dehydrated alfalfa meal, 150 lbs.; ground limestone, 40 lbs.; salt, 10 lbs.; manganese sulfate, 0.25 lb.; riboflavin, 1 gram; vitamin D supplement, 2 lbs.; total, 2,010 lbs. (California Egg Laying Test, 1954.)
3. Ground wheat, 600 lbs.; ground yellow corn, 300 lbs.; ground barley, 180 lbs.;

pulverized oats, 200 lbs.; meat scrap, 50 lbs.; fish meal, 50 lbs.; dried buttermilk or skimmilk, 50 lbs.; soybean oil meal, 374.5 lbs.; dehydrated alfalfa meal, 80 lbs.; ground limestone, 40 lbs.; steamed bone meal or equivalent, 55 lbs.; iodized salt, 15 lbs.; manganese sulfate, 0.5 lb.; vitamin A oil (10,000 I.U. per gram) 2 lbs.; dry vitamin D supplement (1,650 I.C.U. per gram), 2 lbs.; plus riboflavin, vitamin B_{12}, and antibiotic supplements. (Ontario Agricultural College, Circular 142A.)

B. All-mash rations for laying hens

1. High-energy mash. Ground yellow corn, 1,150 lbs.; ground wheat, 300 lbs.; soybean oil meal, 280 lbs.; fish meal, 20 lbs.; meat and bone scrap, 50 lbs.; distillers dried corn solubles, 30 lbs.; alfalfa meal (high-quality), 50 lbs.; dicalcium phosphate, 30 lbs.; ground limestone, 80 lbs.; iodized salt, 10 lbs.; manganese sulfate, 0.4 lb.; riboflavin, 600 milligrams; vitamin D, 680,000 I.C.U.; total, 2,000+ lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.)
2. High-energy mash. Ground yellow corn, 1,223 lbs.; wheat standard middlings, 250 lbs.; soybean oil meal, 200 lbs.; meat and bone scrap, 100 lbs.; fish meal, 40 lbs.; dehydrated alfalfa meal (100,000 I.U. per lb.), 50 lbs.; butyl fermentation product (250 milligrams riboflavin per pound), 20 lbs.; steamed bone meal, 40 lbs.; ground limestone, 60 lbs.; salt, 10 lbs.; manganese sulfate, 0.25 lb.; vitamin A and D feeding oil (2,000 I.U. A and 400 I.C.U. D_3 per gram), 5 lbs.; vitamin B_{12} supplement (3 milligrams B_{12} per pound), 2 lbs.; niacin, 20 grams; total, 2,000.25 lbs. (Singsen, Matterson, and Kozeff, Conn. (Storrs) Bul. 286.)
3. Ground yellow corn, 1,125 lbs.; ground barley or pulverized oats, 100 lbs.; wheat standard middlings, 200 lbs.; soybean oil meal, 250 lbs.; fish meal, 25 lbs.; meat and bone scrap, 50 lbs.; dehydrated alfalfa meal (17% protein, 100,000 I.U. per lb.), 75 lbs.; distillers dried solubles, 50 lbs.; dicalcium phosphate or equivalent, 32 lbs.; ground limestone, 75 lbs.; iodized salt, 10 lbs.; dry vitamin D supplement (1,500 I.C.U. per lb.), 1 lb.; manganese sulfate, 0.25 lb.; niacin, 18 grams; vitamin B_{12} supplement contributing not less than 6 milligrams of vitamin B_{12} per ton of mash; approved antioxidant; total, 1,993.25 lbs. (New England Conference, 1954.)
4. Ground wheat, 1,100 lbs.; ground yellow corn, 455 lbs.; meat and bone scrap, 50 lbs.; fish meal, 30 lbs.; dried buttermilk or skimmilk, 30 lbs.; soybean oil meal, 200 lbs.; dehydrated alfalfa, 50 lbs.; steamed bone meal or equivalent, 35 lbs.; ground limestone, 40 lbs.; iodized salt, 10 lbs.; manganese sulfate, 0.25 lb.; vitamin A oil (10,000 I.U. per gram), 1 lb.; dry vitamin D (1,650 I.C.U. per gram), 1 lb.; plus riboflavin, vitamin B_{12}, and antibiotic supplements. (Ontario Agricultural College Circular 142A.)

C. Mashes for breeders producing hatching eggs

1. Mash to be fed with grain. Ground yellow corn, 735 lbs.; ground wheat, 300 lbs.; soybean oil meal, 430 lbs.; fish meal, 80 lbs.; meat and bone scrap, 100 lbs.; dried whey, 100 lbs.; alfalfa meal (high-quality), 100 lbs.; distillers dried corn solubles, 50 lbs.; dicalcium phosphate, 50 lbs.; ground limestone, 40 lbs.; iodized salt, 15 lbs.; manganese sulfate, 0.5 lb.; riboflavin, 3,200 milligrams; vitamin B_{12}, 3 milligrams; vitamin A, 2,000,000 I.U. (in addition to the high-quality alfalfa meal); vitamin D, 1,360,000 I.C.U.; calcium pantothenate, 4,000 milligrams; total, 2000+ lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.
2. All-mash ration. Ground yellow corn, 1,120 lbs.; ground wheat, 300 lbs.; soybean oil meal, 220 lbs.; fish meal, 50 lbs.; meat and bone scrap, 50 lbs.; dried whey, 50 lbs.; alfalfa meal (high-quality), 50 lbs.; distillers dried corn solubles, 50 lbs.; dicalcium phosphate, 20 lbs.; ground limestone, 80 lbs.; iodized salt, 10 lbs.; manganese sulfate, 0.4 lb.; riboflavin, 1,500 milligrams; vitamin B_{12}, 2 milligrams; vitamin D, 680,000 I.C.U.; calcium pantothenate, 2,000 milligrams; total, 2,000+ lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.)

D. Starter mashes for chicks

1. Ground yellow corn, 925 lbs.; ground wheat, 300 lbs.; soybean oil meal, 475 lbs.; fish meal, 50 lbs.; meat and bone scrap, 50 lbs.; dried whey, 50 lbs.; alfalfa meal (high-quality), 50 lbs.; distillers dried corn solubles, 50 lbs.; dicalcium phosphate, 10 lbs.; ground limestone, 35 lbs.; iodized salt, 5 lbs.; manganese sulfate, 0.4 lb.; riboflavin, 400 milligrams; vitamin B_{12}, 5 milligrams; vitamin D, 540,000 I.C.U.; calcium pantothenate, 800 milligrams; plus antibiotic feed supplement; total, 2,000+ lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.)
2. Ground yellow corn, 1,100 lbs.; wheat standard middlings, 100 lbs.; soybean oil meal, 500 lbs.; fish meal, 100 lbs.; alfalfa meal, 60 lbs.; distillers dried solubles, 50 lbs.; butyl fermentation product, 20 lbs.; dicalcium phosphate or equivalent, 24 lbs.; ground limestone, 30 lbs.; iodized salt, 10 lbs.; manganese sulfate, 0.5 lb.; dry vitamin D supplement (1,500 I.C.U. per gram), 0.5 lb.; niacin, 18 grams; choline chloride, 2.5 lbs.; plus antibiotic-vitamin B_{12} feed supplement and approved antioxidant. (New England College Conference, 1954.)

E. Grower mashes

1. Without pasture, all-mash ration. Ground yellow corn, 1,095 lbs.; ground wheat, 300 lbs.; soybean oil meal, 370 lbs.; fish meal, 30 lbs.; meat and bone scrap, 50 lbs.; dried whey, 25 lbs.; alfalfa meal (high-quality), 50 lbs.; distillers dried corn solubles, 25 lbs.; dicalcium phosphate, 20 lbs.; ground limestone, 30 lbs.; iodized salt, 5 lbs.; manganese sulfate, 0.4 lb.; vitamin B_{12}, 2 milligrams; vitamin D, 270,000 I.C.U.; calcium pantothenate, 2,000 milligrams; plus antibiotic feed supplement, if desired; total, 2,000+ lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.)
2. Mash to be fed with grain, without pasture. Ground yellow corn, 840 lbs.; ground wheat, 300 lbs.; soybean oil meal, 470 lbs.; fish meal, 50 lbs.; meat and bone scrap, 50 lbs.; dried whey, 50 lbs.; alfalfa meal, 100 lbs.; distillers dried corn solubles, 50 lbs.; dicalcium phosphate, 40 lbs.; ground limestone, 40 lbs.; iodized salt, 10 lbs.; manganese sulfate, 0.5 lb.; vitamin B_{12}, 5 milligrams; vitamin D, 540,000 I.C.U.; calcium pantothenate, 3,000 milligrams, plus antibiotic feed supplement, if desired; total, 2,000+ lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.)
3. Mash to be fed with grain on good pasture. Ground corn, 665 lbs.; ground wheat, 600 lbs.; soybean oil meal, 600 lbs.; dicalcium phosphate, 55 lbs.; ground limestone, 60 lbs.; iodized salt, 20 lbs.; manganese sulfate, 0.5 lb.; plus antibiotic feed supplement, if desired; total, 2,000+ lbs. (Hill, Norris, Scott, and Heuser, N.Y., Cornell Feed Service No. 48.)

TABLE VIII. GRAIN FEEDING TABLES FOR DAIRY COWS

It has been emphasized previously that the amount of concentrates, or "grain mixture," to be fed each cow in a herd should be adjusted to her actual production of milk and fat. Otherwise, some cows may be wastefully overfed and others seriously underfed. (**1001**) The common "thumb rules" often used for estimating the amount of grain mixture that should be fed to the various cows are not accurate guides to their real requirements. (**1011**) The amount of grain required by any cow can be determined by computing a balanced ration according to the feeding standards, but to do this for the individual cows in a herd takes considerable time.

The following tables have therefore been prepared to indicate how many pounds of a good concentrate mixture, or so-called "grain mixture," are required by cows producing various amounts of milk of different fat percentages. The first of these tables, Table VIIIa, is for cows not on pasture, and the second one, Table VIIIb, is for cows which are on pasture. Sufficient amounts of grain mixture are advised to meet the higher set of recommendations in the Morrison feeding standards. (Appendix Table III.) When grain and other concentrates are very high in price in comparison with roughages, then it may be advisable to feed smaller amounts of grain mixture than shown in these tables. (**1025–1027**)

The amounts of grain mixture advised are for mature cows during the chief part of the lactation period. As has been emphasized previously, the amount of grain mixture should be increased very gradually after a cow freshens. (**1031**) Three weeks or more should be taken to get high producers on full feed. Even at that time and for a few weeks thereafter, high producers are often unable to consume safely as much grain as would be required to produce the amount of milk they are yielding. They therefore draw temporarily on the store of nutrients in their bodies.

During the last 2 to 3 months of pregnancy, good cows should be fed somewhat more grain mixture than shown in the tables. This is to provide the additional nutrients needed for the development of the unborn calf and to get the cow into proper condition for the next lactation. (**1082**) Since heifers need additional feed for the growth of their own bodies, it is wise to feed them a little more liberally than the amounts shown in the tables. (See Appendix Table III.)

Table VIIIa. Grain feeding table for cows not on pasture.—The amount of the grain mixture that it is necessary to feed daily to any particular cow will depend not only on the amount of milk she gives and on its richness in fat, but also on the amount and quality of the roughage she consumes. Also, it will depend to some extent on her live weight.

This table therefore gives recommendations for three different rates of roughage feeding, as shown by the first three columns. The second column, in bold-faced type, gives the figures for the most common rate of feeding roughage to dairy cows. This rate is to feed approximately 2 lbs. of good hay daily per 100 lbs. live weight, or the equivalent in other good roughage (for example, 1 lb. of good hay and 3 lbs. of silage).

When cows are fed *very liberally* on roughage of *excellent quality* and the allowance of grain is restricted to their needs, they will consume per 100 lbs. live weight about 2.5 lbs. of hay equivalent. The first column of figures is designed to fit these conditions.

The third column of figures is for use when cows are fed a scanty allowance of good roughage, or when they are fed as much poor roughage as they will consume without undue waste. This column is designed for use when cows consume only about the equivalent of 1.5 lbs. of good hay daily per 100 lbs. live weight.

In using the table, first estimate approximately the number of pounds of hay equivalent the cows are actually consuming daily per 100 lbs. live weight, after deducting the wastage. In making this estimate, use the following conversion factors for converting the amounts of other roughages actually consumed

into the equivalent amounts of good hay. (Good-quality legume hay or well-cured, early-cut grass hay is taken as the standard.)

Fair-quality hay	80 per cent
Poor-quality hay; cut or shredded corn or sorghum stover	60 per cent
Good silage; potatoes.......	33 per cent
Mangels; rutabagas; cabbage	20 per cent
Oat straw; barley straw	50 per cent

After estimating the pounds of good hay equivalent consumed per 100 lbs. live weight, then use the particular one of the first three columns that most nearly fits the rate of roughage feeding. Go down this column to the amount of milk given by the particular cow, and then follow the horizontal row of figures across the table to the right until the column is reached for milk having the percentage of fat nearest to that of the milk produced by the cow. The figure in this column shows the pounds of grain mixture to be fed daily to the cow.

To illustrate the use of the table, let us assume that a cow yielding 36 lbs. of milk containing 3.5 per cent fat is being fed approximately 2.0 lbs. of good hay equivalent per 100 lbs. live weight. We go down the second column, which is for this rate of roughage feeding, until we come to the figure 36. We then go horizontally to the right across the table until we reach the column for 3.5 per cent fat, where we find the figure 10.8. Therefore this cow should be fed 10.8 lbs. of a good grain mixture daily to meet her requirements.

Adjustment for difference in live weights.—The amounts of grain mixture required by different cows producing the same amount and richness of milk depend somewhat on their respective live weights. When fed roughage at the usual rate, for each additional 100 lbs. a cow weighs in comparison with a smaller cow, she will consume approximately 2 lbs. more hay equivalent. This furnishes about 1.0 lb. total digestible nutrients. However, for each 100 lbs. increase in body weight, she requires for maintenance only about 0.65 to 0.70 lb. more total digestible nutrients. Therefore, for each 100 lbs. of additional body weight, she will have available for milk production approximately 0.35 to 0.30 lb. of total digestible nutrients. This will save about 0.4 lb. of grain mixture.

This table and Table VIIIb have been computed for cows of the following average weights:

For 3.0, 3.5 and 4.0% milk	1,200 lbs. weight
For 4.5 and 5.0% milk	1,000 lbs. weight
For 5.5 and 6.0% milk	850 lbs. weight

There will be no important error in using the tables for cows of other weights, unless the difference in weight is too great. If greater accuracy is desired, 0.4 lbs. should be deducted from the amount of grain mixture recommended in the table, for each 100 lbs. the weight of a given cow exceeds the standard weights shown above. If the weight of a cow is considerably less than these standard weights, 0.4 lb. should be added to the recommended amount of grain mixture for each 100 lbs. she weighs less than the standard used in the table for cows producing milk containing the given percentage of fat.

Table VIIIb. Grain feeding table for cows on pasture.—This table shows the approximate amounts of a good concentrate mixture, or "grain mixture," required per head daily by cows on excellent, good, and fair pasture. The method of using this table is similar to that for Table VIIIa.

The column of figures for excellent pasture is to be used for cows which are on pasture that provides an abundance of very palatable, nutritious forage. Such forage is furnished by usual grass pasture only during the flush of growth in late spring and early summer. Only pasture that is liberally fertilized and also well managed will generally furnish such pasturage later in the season.

The second column of figures, which is for good pasture, is for use when the cows have a plentiful supply of good pasturage, but when the pasture can hardly be called excellent. On such pasture the

cows must be able to secure somewhat more feed from the pasture than they do from a full feed of good hay and average silage in winter.

The third column of figures is for use when the cows are on fair pasture, but not on pasture that is distinctly poor. On poor pasture cows will need fully as large an allowance of grain mixture as when fed roughage at the rate shown in the third column of Table VIIIa.

If a cow differs considerably in live weight from the weight used in computing this table, adjustments in the amount of grain mixture should be made, as previously stated in this explanation.

These tables have been adapted from tables prepared by Mr. J. W. Avery, formerly in charge of the Central Dairy Record Club Laboratory of the New York State College of Agriculture, and by Professor W. T. Crandall of the Department of Animal Husbandry of the New York State College of Agriculture, Cornell University.

TABLE VIIIa. Grain feeding table for cows not on pasture

Hay equivalent consumed per 100 lbs. of live weight daily			Total pounds of grain mixture or concentrates to feed						
2½ lbs. Very liberal feeding of good roughage	2 lbs. Usual rate of feeding good hay or good hay and silage	1½ lbs. Feeding scanty amount of good roughage or feeding poor roughage	Percentage of fat in milk						
Milk produced daily, pounds			3.0%	3.5%	4.0%	4.5%	5.0%	5.5%	6.0%
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
17	**10**	..	....	....	....	1.9	2.2	3.1	3.5
19	**12**	..	....	....	1.6	2.8	3.2	4.2	4.6
21	**14**	..	1.5	2.0	2.4	3.8	4.2	5.3	5.7
23	**16**	9	2.3	2.8	3.3	4.7	5.2	6.3	6.8
25	**18**	11	3.0	3.6	4.2	5.6	6.2	7.4	8.0
27	**20**	13	3.7	4.4	5.0	6.5	7.2	8.4	9.1
29	**22**	15	4.5	5.2	5.9	7.5	8.2	9.5	10.2
31	**24**	17	5.2	6.0	6.8	8.4	9.2	10.5	11.3
33	**26**	19	6.0	6.8	7.6	9.3	10.2	11.6	12.5
35	**28**	21	6.7	7.6	8.5	10.3	11.2	12.7	13.6
37	**30**	23	7.4	8.4	9.3	11.2	12.2	13.7	14.7
39	**32**	25	8.2	9.2	10.2	12.1	13.2	14.8	15.8
41	**34**	27	8.9	10.0	11.1	13.1	14.2	15.8	17.0
43	**36**	29	9.6	10.8	11.9	14.0	15.1	16.9	18.1
45	**38**	31	10.4	11.6	12.8	14.9	16.1	18.0	19.2
47	**40**	33	11.1	12.4	13.7	15.9	17.1	19.0	20.3
49	**42**	35	11.8	13.2	14.5	16.8	18.1	20.1	21.5
51	**44**	37	12.6	14.0	15.4	17.7	19.1	21.1	22.6
53	**46**	39	13.3	14.8	16.3	18.7	20.1	22.2	23.7
55	**48**	41	14.1	15.6	17.1	19.6	21.1	23.3	
57	**50**	43	14.8	16.4	18.0	20.5	22.1		
59	**52**	45	15.5	17.2	18.9	21.4	23.1		
61	**54**	47	16.3	18.0	19.7	22.4			
63	**56**	49	17.0	18.8	20.6	23.3			
65	**58**	51	17.7	19.6	21.4	24.2			
67	**60**	53	18.5	20.4	22.3				
69	**62**	55	19.2	21.2	23.2				
71	**64**	57	19.9	22.0	24.0				
73	**66**	59	20.7	22.8	24.9				
75	**68**	61	21.4	23.6	25.8				

Regardless of the amount of grain theoretically required by a cow, she should not be fed more than she can safely handle.

Table VIIIb. Grain feeding table for cows on pasture

Quality of pasture			Total pounds of grain mixture or concentrates to feed						
Excellent	Good	Fair	Percentage of fat in milk						
Milk produced daily			3.0%	3.5%	4.0%	4.5%	5.0%	5.5%	6.0%
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
22	13	..	....	....	....	....	....	....	1.2
24	15	..	....	....	....	....	1.2	2.0	2.3
26	17	..	....	....	....	1.9	2.2	3.1	3.5
28	19	10	....	....	1.6	2.8	3.2	4.2	4.6
30	21	12	1.5	2.0	2.4	3.8	4.2	5.3	5.7
32	23	14	2.3	2.8	3.3	4.7	5.2	6.3	6.8
34	25	16	3.0	3.6	4.2	5.6	6.2	7.4	8.0
36	27	18	3.7	4.4	5.0	6.5	7.2	8.4	9.1
38	29	20	4.5	5.2	5.9	7.5	8.2	9.5	10.2
40	31	22	5.2	6.0	6.8	8.4	9.2	10.5	11.3
42	33	24	6.0	6.8	7.6	9.3	10.2	11.6	12.5
44	35	26	6.7	7.6	8.5	10.3	11.2	12.7	13.6
46	37	28	7.4	8.4	9.3	11.2	12.2	13.7	14.7
48	39	30	8.2	9.2	10.2	12.1	13.2	14.8	15.8
50	41	32	8.9	10.0	11.1	13.1	14.2	15.8	17.0
52	43	34	9.6	10.8	11.9	14.0	15.1	16.9	18.1
54	45	36	10.4	11.6	12.8	14.9	16.1	18.0	19.2
56	47	38	11.1	12.4	13.7	15.9	17.1	19.0	20.3
58	49	40	11.8	13.2	14.5	16.8	18.1	20.1	21.5
60	51	42	12.6	14.0	15.4	17.7	19.1	21.1	22.6
62	53	44	13.3	14.8	16.3	18.7	20.1	22.2	23.7
64	55	46	14.1	15.6	17.1	19.6	21.1	23.3	Regard-
66	57	48	14.8	16.4	18.0	20.5	22.1		less of the
68	59	50	15.5	17.2	18.9	21.4	amount of grain		
70	61	52	16.3	18.0	19.7	22.4	theoretically required		
72	63	54	17.0	18.8	20.6	23.3	by a cow, she should not		
74	65	56	17.7	19.6	21.4	be fed more than she can safely handle.			

Table IX. Estimating Weights of Dairy Cattle from Heart Girths

In computing balanced rations for dairy cows and other dairy cattle, it is necessary to know their approximate live weights. If one does not have suitable scales available for weighing the cattle, their weights can be estimated approximately by measuring the heart girth, or chest girth. In finding the heart girth, an accurate tape measure should be placed around the animal directly back of the front legs. The animal should stand squarely on all four legs.

A mature cow is heavier than an immature cow having the same heart girth. Investigations by the Illinois and Nebraska Stations show that the most accurate estimate of the live weights of cows during the first month of lactation can be made if the number of inches shown in the first table is added to the actual heart girth. (Gaines, Davis, and Morgan, Journal Dairy Science, 24, 1941, pp. 983–992.) This gives the modified heart girth.

Add the following number of inches to the actual heart girth

	Jerseys Inches	Guernseys Inches	Ayrshires Inches	Holsteins Inches
Less than 3 years old	0	2	2	6
3 to 4 years old	2	4	4	8
5 years old or more	2	5	5	9

After the actual heart girth has been modified by using the preceding table, the estimated heart girth is found in the table below:

Estimated live weights of dairy cows from modified heart girths

Mod. heart girth	Weight	Mod. heart girth	Weight	Mod. heart girth	Weight	Mod. heart girth	Weight	Mod. heart girth	Weight
Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches	Lbs.
50	475	60	666	70	886	80	1134	90	1411
51	493	61	687	71	910	81	1163	91	1440
52	511	62	708	72	934	82	118[illegible]	92	1469
53	530	63	729	73	958	83	1214	93	1499
54	548	64	751	74	982	84	1242	94	1529
55	567	65	773	75	1007	85	1269	95	1559
56	586	66	795	76	1032	86	1297	96	1589
57	606	67	817	77	1057	87	1325	97	1620
58	626	68	840	78	1082	88	1353	98	1651
59	646	69	863	79	1108	89	1382	99	1683

The approximate live weights of dairy heifers may be estimated from the actual heart girths by the use of the following table, based on studies by the Nebraska and Missouri Stations. (Davis, Morgan, Brody, and Ragsdale, Nebraska Research Bulletin 91.)

Estimated weights of dairy heifers having various heart girths

Heart girth	Weight	Heart girth	Weight	Heart girth	Weight	Heart girth	Weight	Heart girth	Weight
Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches	Lbs.
25	52	30	87	35	135	40	196	45	274
26	58	31	95	36	146	41	211	46	292
27	64	32	104	37	157	42	226	47	311
28	71	33	114	38	170	43	241	48	330
29	78	34	124	39	183	44	257	49	350

Tables X. Amino Acid Content of Certain Feeds

Amino acids in feeds.—The information concerning the amounts of the essential amino acids in feeds is still very limited, because of the expense and difficulty in making such determinations. The following tables show the approximate content of these amino acids in important feeds, so far as data are available. Very little information has been secured concerning the amounts of the essential amino acids in roughages, except alfalfa meal and alfalfa hay.

It must be borne in mind that for most feeds amino acid determinations have been made on only a few lots of the feed, and the results have often differed appreciably. However, the tables indicate which feeds are low and which are higher in the amino acids that are most apt to be deficient in rations for non-ruminants, especially pigs and poultry. These amino acids are lysine, tryptophan, and methionine.

As cystine can partially replace methionine in a ration, the tables also state the approximate content of cystine, where cystine determinations have been reported. Cystine itself is not an essential amino acid.

The first table, Table Xa, states the percentages of the several amino acids in the entire feed, as fed. The second table, Table Xb, gives the percentages of the amino acids in the **protein** of each feed.

Because feeds differ so widely in percentage of total protein they contain, Table Xb indicates better than Table Xa whether the protein in a particular feed is a good or a poor source of the important essential amino acids.

Sources of data.—The data presented in these tables are based on a compilation of available data, made by the author. Much data has been provided by the recent compilation of analyses of by-product concentrates made by Donald E. Miller, technical secretary of the Committee on Feed Composition of the National Research Council. The author is a member of this committee and cooperated in the compilation by supplying data he had compiled. This compilation has just been published in preliminary form by the National Research Council.

Analyses have been included from the following sources: Williams, Essential Amino Acid Content of Animal Feeds, New York (Cornell) Memoir 337, 1955; Almquist, Proteins and Amino Acids in Nutrition, edited by Sahyun, 1948, p. 231; Schweigert, Texas, Poultry Science, 27, 1948, pp. 223–227; Block and Bolling, The Amino Acid Composition of Proteins and Foods, 1945.

The author has also compiled amino acid analyses published in the bulletins and reports of the agricultural experiment stations and in other scientific publications.

Table Xa. Percentages of amino acids in certain feeds

Feeding stuff	Arginine	Cystine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Alfalfa hay	0.8	...	...	...	0.3	1.0	1.1
Alfalfa-bromegrass hay	0.7	...	...	...	0.3	0.8	1.0
Alfalfa meal, dehydrated, 17% protein	0.8	0.4	...	...	0.3	0.9	1.3
Babassu oil meal	2.9	...	...	...	0.4	1.1	1.4
Barley grain	0.6	0.2	...	...	0.2	0.5	0.8
Beet pulp, dried	0.3	...	...	...	0.2	0.3	0.6
Blood flour	3.4	...	...	...	4.9	1.1	10.6
Blood meal	3.5	1.4	...	...	4.2	1.0	10.3
Brewers' grains, dried	1.3	...	...	...	0.5	1.5	2.3
Buttermilk, dried	1.1	...	7.3	...	0.9	2.7	3.4

TABLE Xa. Percentages of amino acids in certain feeds—*continued*

Feeding stuff	Arginine	Cystine	Glutamic acid	Glycine	Histi-dine	Iso-leucine	Leucine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Cereals, young, dehydrated	...	...	2.6	...	...	1.3	1.5
Cereals, young, green pasture	...	...	0.6	...	...	0.3	0.3
Coconut oil meal	2.2	...	...	...	0.3	1.0	1.4
Corn, dent, Grade No. 2	0.4	0.1	2.8	0.4	0.2	0.4	0.9
Corn gluten feed	0.8	...	4.3	...	0.6	1.3	2.7
Corn gluten meal	1.4	0.6	8.3	1.5	1.0	2.3	7.6
Corn oil meal	1.1	0.5	3.0	1.1	0.6	1.1	1.7
Cottonseed meal	3.3	1.0	6.3	2.4	0.9	1.5	2.2
Cowpeas	1.7	...	...	...	0.7	1.1	2.3
Crab meal	1.7	...	...	...	0.5	1.2	1.6
Distillers dried corn grains, with solubles	0.9	...	5.5	0.5	0.7	1.7	2.2
Distillers dried corn grains, without solubles	1.0	...	...	...	0.6	1.0	3.6
Distillers dried rye grains, with solubles	1.0	...	5.5	...	0.7	1.5	2.1
Distillers dried wheat grains, with solubles	1.1	...	8.6	...	0.8	1.9	2.0
Distillers solubles, dried, corn	1.0	0.6	4.3	1.1	0.7	1.5	2.1
Distillers solubles, dried, rye	1.0	...	...	...	0.7	1.8	1.8
Distillers solubles, dried, sorghum	1.0	...	7.2	...	0.9	0.9	1.7
Distillers solubles, dried, wheat	1.0	...	9.2	...	0.8	1.6	1.5
Fish meal, all analyses	3.9	0.8	8.4	4.4	1.5	3.6	5.1
Fish meal, herring	4.0	1.6	...	5.0	1.3	3.2	5.1
Fish meal, menhaden	4.0	...	...	...	1.6	4.2	5.0
Fish meal, redfish	4.1	...	...	...	1.3	3.5	4.9
Fish meal, salmon, vacuum dried	5.6	...	...	...	1.8	3.8	6.5
Fish meal, sardine	2.7	0.8	...	4.5	1.8	...	...
Fish solubles, condensed	2.2	1.4	4.9	5.3	2.4	1.5	2.2
Fish solubles, dried	2.6	...	...	...	1.3	2.1	3.7
Hominy feed	0.4	...	...	...	0.2	0.4	0.9
Linseed meal	2.8	0.6	...	...	0.7	1.9	2.0
Liver meal, animal	4.1	0.9	8.1	5.6	1.5	3.3	5.4
Meat scrap, 55% protein	3.7	0.6	8.1	2.2	1.1	1.9	3.5
Meat and bone scrap, 50% protein	4.0	0.6	11.0	6.6	0.9	1.7	3.1
Milk cow's	0.14	...	...	...	0.10	0.33	0.26
Milk, cow's colostrum	0.64	...	...	...	0.35	0.71	1.30
Milk, ewe's	0.25	...	...	...	0.18	0.40	0.62
Milk, mare's	0.14	...	...	...	0.06	0.14	0.19
Milk, sow's	0.41	...	...	...	0.20	0.42	0.59
Milo grain	0.4	0.2	...	...	0.2	0.6	1.4
Oat grain	0.7	0.2	...	...	0.2	0.7	1.0
Oat meal, or rolled oats	1.0	...	...	...	0.3	0.5	1.1
Oat mill by-product	0.2	...	...	...	0.1	0.2	0.3
Pea seed, field	2.1	0.3	...	...	...	...	...
Peanut oil meal, solvent process	5.9	0.7	...	2.5	1.2	2.0	3.7
Rice, polished	0.6	0.1	...	0.8	...	...	...
Rice bran	0.5	0.1	...	...	0.2	...	...
Rice polishings	0.5	0.1	...	...	0.1	...	...

TABLE Xa. Percentages of amino acids in certain feeds—*continued.*

Feeding stuff	Arginine	Cystine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Rye grain	0.5	0.2	...	...	...	...	...
Safflower-seed oil meal, well-hulled	5.4	...	...	2.5	...	...	...
Sesame oil meal	4.3	0.6	...	4.0	1.1	1.6	2.8
Skimmilk, dried	1.2	0.5	6.8	0.2	0.9	2.3	3.3
Sorghum gluten feed	1.0	...	...	...	0.6	1.0	2.5
Sorghum gluten meal	1.2	...	...	...	0.8	2.3	7.4
Soybean oil meal, expeller process	2.6	0.6	7.5	2.5	1.1	2.8	3.6
Soybean oil meal, solvent process	3.2	...	8.2	...	1.1	2.5	3.4
Sunflower-seed oil meal, well-hulled	3.8	0.7	...	1.8	...	...	...
Tankage, digester, 60% protein	3.6	...	...	...	1.9	1.9	5.1
Wheat bran	1.0	0.3	...	0.9	0.3	0.6	0.9
Wheat flour	0.4	...	3.7	...	0.3	0.6	0.9
Wheat germ	1.6	0.5	...	...	0.5	1.2	1.1
Wheat grain, hard spring	0.7	0.2	...	0.9	0.2	0.7	1.0
Wheat red dog	1.0	...	...	...	0.4	0.7	1.2
Wheat standard middlings	0.9	0.2	4.1	0.4	0.4	0.8	1.2
Whey, dried	0.4	0.3	1.7	...	0.2	0.9	1.4
Whey product, dried	1.0	...	...	...	0.1	0.3	0.2
Yeast, brewers', dried	2.2	0.5	...	1.7	1.1	2.2	3.2
Yeast, torula, dried	2.6	0.6	...	2.7	1.4	2.9	3.5

TABLE Xa. Percentages of amino acids in certain feeds—*continued.*

Feeding stuff	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Alfalfa hay	1.1	0.1	0.7	0.6	0.2	0.5	0.7
Alfalfa-bromegrass hay	0.6	0.1	0.6	0.7	0.1	...	0.7
Alfalfa meal, dehydrated, 17% protein	1.1	0.1	0.8	0.7	0.3	0.6	0.8
Babassu oil meal	0.9	0.3	0.9	0.6	0.2	0.4	1.1
Barley grain	0.4	0.16	0.6	0.4	0.1	...	0.6
Beet pulp, dried	0.6	0.01	0.3	0.4	0.1	0.4	0.4
Blood flour	8.3	1.1	5.7	3.7	1.0	2.0	7.4
Blood meal	6.9	0.9	6.1	3.7	1.1	1.8	6.5
Brewers' grains, dried	0.9	0.4	1.3	0.9	0.4	1.2	1.5
Buttermilk, dried	2.4	0.7	1.5	1.6	0.5	1.0	2.8
Cereals, young, dehydrated	1.9	0.4	1.1	1.1	0.2	...	1.3
Cereals, young, green pasture	0.4	0.08	0.2	0.2	0.04	...	0.3
Coconut oil meal	0.5	0.3	0.8	0.6	0.2	0.6	1.0
Corn, dent, Grade No. 2	0.2	0.1	0.4	0.3	0.08	0.4	0.3
Corn gluten feed	0.8	0.3	1.0	0.8	0.2	0.9	1.3
Corn gluten meal	0.8	1.0	2.9	1.4	0.2	1.0	2.2
Corn oil meal	0.9	0.3	0.8	0.9	0.3	1.5	1.3
Cottonseed meal	1.6	0.5	1.9	1.1	0.5	1.0	1.8
Cowpeas	2.1	0.2	1.3	0.8	0.3	1.1	1.2
Crab meal	1.4	0.5	1.2	1.0	0.3	1.2	1.5

TABLE Xa. Percentages of amino acids in certain feeds—*continued.*

Feeding stuff	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Distillers dried corn grains, with solubles	0.7	0.5	1.7	1.0	0.1	0.6	1.6
Distillers dried corn grains, without solubles	0.9	0.4	0.6	0.3	0.2	0.9	1.2
Distillers dried rye grains, with solubles	1.0	0.4	1.3	1.1	0.3	0.5	1.6
Distillers dried wheat grains, with solubles	0.8	0.5	1.9	1.0	0.4	0.6	1.9
Distillers solubles, dried, corn	0.9	0.6	1.5	1.0	0.2	0.7	1.5
Distillers solubles, dried, rye	0.6	0.5	1.7	1.1	0.2	0.6	1.9
Distillers solubles, dried, sorghum	0.9	0.5	1.8	1.0	0.3	0.9	2.0
Distillers solubles, dried, wheat	0.7	0.4	1.7	1.0	0.5	0.7	1.5
Fish meal, all analyses	6.4	1.8	2.6	2.8	0.7	1.8	3.5
Fish meal, herring	7.3	2.0	2.6	2.6	0.9	2.1	3.2
Fish meal, menhaden	5.3	1.8	2.7	2.9	0.6	1.6	3.6
Fish meal, redfish	6.6	1.8	2.5	2.6	0.6	1.7	3.3
Fish meal, salmon, vacuum dried	8.2	1.8	3.2	3.7	0.7	2.0	4.2
Fish meal, sardine	5.9	...	2.0	2.6	0.5	...	...
Fish solubles, condensed	2.4	1.0	1.3	1.1	0.7	...	1.4
Fish solubles, dried	3.9	1.2	1.6	1.3	0.4	0.9	2.5
Hominy feed	0.4	0.1	0.4	0.4	0.1	0.5	0.5
Linseed meal	1.3	0.5	1.5	1.2	0.5	1.0	1.7
Liver meal, animal	4.8	1.3	2.9	2.6	0.6	1.7	4.2
Meat scrap, 55% protein	3.8	0.8	1.9	1.8	0.3	0.9	2.6
Meat and bone scrap, 50% protein	3.5	0.7	1.8	1.8	0.2	...	2.4
Milk, cow's	0.26	0.07	0.17	0.17	0.05	...	0.26
Milk, cow's colostrum	1.10	0.26	0.63	0.97	0.25	...	1.13
Milk, ewe's	0.52	0.17	0.33	0.31	0.09	...	0.49
Milk, mare's	0.14	0.04	0.10	0.09	0.03	...	0.16
Milk, sow's	0.50	0.14	0.34	0.37	0.09	...	0.45
Milo grain	0.1	0.5	0.3	0.1	0.4	0.4	0.5
Oat grain	0.4	0.2	0.7	0.4	0.15	0.4	0.7
Oat meal, or rolled oats	0.6	0.2	0.7	0.5	0.2	0.7	0.7
Oat mill by-product	0.2	0.1	0.2	0.2	0.1	0.2	0.2
Pea seed, field	1.2	0.2	...	...	0.2	...	...
Peanut oil meal, solvent process	2.3	0.4	2.7	1.5	0.5	1.8	2.8
Rice, polished	0.3	0.3	...	...	0.1	...	...
Rice bran	0.5	...	...	0.4	0.1	...	...
Rice polishings	0.5	...	...	0.3	0.1	...	...
Rye grain	0.4	0.16	...	...	0.14	...	...
Safflower-seed oil meal, well-hulled	1.3	0.7	...	0.8	...	...	...
Sesame oil meal	1.2	1.2	2.0	1.6	0.6	2.0	2.2
Skimmilk, dried	2.8	0.8	1.5	1.4	0.4	1.3	2.2
Sorghum gluten feed	0.8	0.3	1.0	0.8	0.2	...	1.3
Sorghum gluten meal	0.7	0.7	2.6	1.4	0.4	...	2.5
Soybean oil meal, expeller process	2.7	0.7	2.1	1.7	0.6	1.4	2.2
Soybean oil meal, solvent process	2.9	0.6	2.2	1.7	0.6	1.4	2.4

TABLE Xa. Percentages of amino acids in certain feeds—*continued.*

Feeding stuff	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Sunflower-seed oil meal, well-hulled	1.8	1.6	...	...	0.6	...	...
Tankage, digester, 60% protein	4.0	0.8	2.7	2.4	0.7	...	4.2
Wheat bran	0.6	0.1	0.5	0.4	0.3	0.4	0.7
Wheat flour	0.3	0.1	0.6	0.3	0.1	0.2	0.5
Wheat germ	1.6	0.3	0.8	0.8	0.3	0.8	1.1
Wheat grain, hard spring	0.4	0.2	0.8	0.4	0.14	...	0.7
Wheat red dog	0.6	0.1	0.5	0.5	0.2	0.5	0.8
Wheat standard middlings	0.7	0.2	0.7	0.6	0.2	0.4	0.8
Whey, dried	1.1	0.2	0.4	0.8	0.2	0.3	0.7
Whey product, dried	...	0.1	0.1	0.5	0.1	0.2	0.3
Yeast, brewers', dried	3.0	0.7	1.8	2.1	0.5	1.5	2.3
Yeast, torula, dried	3.8	0.8	3.0	2.6	0.5	2.1	2.9

Table Xb. Percentages of amino acids in **protein** of feeds

Feeding stuff	Arginine	Cystine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Alfalfa hay	5.2	...	...	...	2.0	6.5	7.2
Alfalfa-bromegrass hay	5.9	...	...	...	2.5	6.8	8.5
Alfalfa meal, dehydrated, 17% protein	4.5	...	...	...	1.7	5.1	7.4
Babassu oil meal	12.0	...	...	...	1.7	4.5	5.8
Barley grain	4.6	1.4	...	...	1.4	4.1	6.6
Beet pulp, dried	3.4	...	...	...	2.3	3.4	6.8
Blood flour	4.0	...	...	...	6.8	1.4	12.5
Blood meal	4.3	1.7	...	...	5.1	1.2	12.5
Brewers' grains, dried	4.7	...	...	...	1.8	5.5	8.4
Buttermilk, dried	3.5	...	23.0	...	2.8	8.5	10.7
Cereals, young, dehydrated	...	...	11.7	...	...	5.8	6.7
Coconut oil meal	10.4	...	...	...	1.4	4.7	6.6
Corn, dent, Grade No. 2	4.5	1.1	32.2	4.6	2.5	4.5	10.6
Corn gluten feed	3.4	...	17.3	...	2.4	5.2	10.8
Corn gluten meal	3.2	1.4	19.2	3.5	2.3	5.3	17.6
Corn oil meal	4.9	2.2	13.4	4.9	2.7	4.9	7.6
Cottonseed meal	8.0	2.4	15.1	5.8	2.2	3.7	5.3
Cowpeas	7.4	...	...	...	2.8	4.5	9.9
Crab meal	5.4	...	...	...	1.6	3.8	5.1
Distillers dried corn grains, with solubles	3.4	...	20.7	1.9	2.6	6.4	8.3
Distillers dried corn grains, without solubles	3.8	...	...	...	2.3	3.8	13.8
Distillers dried rye grains, with solubles	4.1	...	22.5	...	2.9	6.1	8.6
Distillers dried wheat grains, with solubles	3.8	...	30.0	...	2.8	6.6	7.0
Distillers solubles, dried, corn	3.5	2.1	15.1	3.9	2.5	5.3	7.4
Distillers solubles, dried, rye	2.8	...	...	...	2.0	5.1	5.1
Distillers solubles, dried, sorghum	3.8	...	27.3	...	3.4	3.4	6.4
Distillers solubles, dried, wheat	3.0	...	27.8	...	2.4	4.8	4.5
Fish meal, all analyses	6.5	1.3	13.8	7.2	2.5	6.0	8.4
Fish meal, herring	5.5	2.2	...	6.9	1.8	4.4	7.0
Fish meal, menhaden	6.4	...	...	...	2.6	6.8	8.1
Fish meal, redfish	7.1	...	...	...	2.3	6.1	8.6
Fish meal, salmon, flame dried	8.6	...	...	...	3.0	6.4	8.1
Fish meal, sardine	4.1	1.2	...	6.9	2.8	...	...
Fish solubles, condensed	7.2	4.6	16.2	17.3	8.0	5.0	7.3
Fish solubles, dried	4.2	...	...	...	2.0	3.4	5.9
Hominy feed	4.2	...	...	...	1.9	3.3	8.0
Linseed meal	8.1	1.7	...	...	2.0	5.4	5.7
Liver meal, animal	6.1	1.4	12.2	8.5	2.3	5.0	8.1
Meat scrap, 55% protein	6.7	1.1	14.8	4.0	2.0	3.5	6.4
Meat and bone scrap, 50% protein	8.0	1.2	22.1	13.3	1.8	3.4	6.2
Milk, cow's	4.1	...	...	...	2.9	6.6	9.4
Milk, cow's colostrum	4.6	...	...	...	2.5	5.0	9.3
Milk, ewe's	3.9	...	...	...	2.8	6.2	9.5
Milk, mare's	6.8	...	...	...	3.0	6.9	9.3
Milk, sow's	5.6	...	...	...	2.7	5.8	8.1

TABLE Xb. Percentages of amino acids in **protein** of feeds—*continued.*

Feeding stuff	Arginine	Cystine	Glutamic acid	Glycine	Histi-dine	Iso-leucine	Leucine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Milo grain	3.5	1.8	...	...	1.8	5.1	13.1
Oat grain	5.8	1.5	...	...	1.9	5.7	8.2
Oat meal, or rolled oats	6.2	...	...	...	1.9	3.1	6.8
Oat mill by-product	4.9	...	...	...	2.4	4.9	7.3
Pea seed, field	9.0	1.3	...	...	...	...	...
Peanut oil meal, solvent process	12.5	1.5	...	5.3	2.5	4.2	7.9
Rice, polished	7.8	1.5	...	11.1	...	...	...
Rice bran	4.0	0.8	...	...	1.6	...	...
Rice polishings	3.9	0.8	...	...	0.8	...	...
Rye grain	4.1	1.4	...	...	...	...	...
Safflower-seed oil meal, well-hulled	12.7	...	...	5.9	...	...	...
Sesame oil meal	10.0	1.4	...	9.2	2.5	3.7	6.4
Skimmilk, dried	3.5	1.5	20.5	0.6	2.7	6.9	10.0
Sorghum gluten feed	4.0	...	...	...	2.4	4.0	10.0
Sorghum gluten meal	2.9	...	...	...	1.9	5.5	17.8
Soybean oil meal, expeller process	6.0	1.4	17.0	5.7	2.5	6.4	8.2
Soybean oil meal, solvent process	7.0	...	17.9	...	2.4	5.6	7.4
Sunflower-seed oil meal	7.7	1.4	...	3.6	...	...	...
Tankage, digester, 60% protein	6.1	...	...	...	3.2	3.2	8.6
Wheat bran	6.1	1.8	...	5.5	1.8	3.7	5.5
Wheat flour	3.7	...	34.3	...	2.8	5.6	8.3
Wheat germ	5.9	1.9	...	...	4.5	4.3	6.0
Wheat grain, hard spring	3.7	1.3	...	5.3	1.3	4.1	5.8
Wheat red dog	5.6	...	...	...	2.2	3.8	6.7
Wheat standard middlings	5.3	1.2	23.8	2.3	2.3	4.7	7.0
Whey, dried	3.0	2.3	13.3	...	1.6	7.0	10.9
Whey product, dried	6.5	...	...	...	0.7	2.0	1.3
Yeast, brewers', dried	4.9	1.1	...	3.8	2.4	4.8	7.1
Yeast, torula, dried	5.6	1.3	...	5.8	3.0	6.2	7.5

TABLE Xb. Percentages of amino acids in **protein** of feeds—*continued.*

Feeding stuff	Lysine	Methi-onine	Phenyl-alanine	Threo-nine	Trypto-phan	Tyro-sine	Valine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Alfalfa hay	7.2	0.6	4.6	3.9	1.3	3.3	4.6
Alfalfa-bromegrass hay	5.1	0.8	5.1	5.9	0.8	...	5.9
Alfalfa meal, dehydrated, 17% protein	6.3	0.6	4.5	4.0	1.7	3.4	4.5
Babassu oil meal	3.7	1.2	3.7	2.5	0.8	1.7	4.5
Barley grain	3.1	1.3	4.8	3.0	0.9	...	4.9
Beet pulp, dried	6.8	0.1	3.4	4.5	1.1	4.5	4.5
Blood flour	9.9	1.3	6.7	4.4	1.2	2.4	8.8
Blood meal	8.4	1.1	7.4	4.5	1.3	2.2	7.9
Brewers' grains, dried	3.3	1.3	4.7	3.3	1.3	4.2	5.6
Buttermilk, dried	7.5	2.2	4.7	5.0	1.6	3.1	8.8

TABLE Xb. Percentages of amino acids in protein of feeds—*continued.*

Feeding stuff	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Cereals, young, dehydrated	8.5	1.6	4.8	4.8	0.8	...	5.9
Coconut oil meal	2.4	1.4	3.8	2.8	0.9	2.8	4.7
Corn, dent, Grade No. 2	2.5	1.3	4.5	3.4	0.9	4.5	3.8
Corn gluten feed	3.3	1.2	3.8	3.3	0.8	3.7	5.2
Corn gluten meal	1.9	2.3	6.7	3.2	0.5	2.3	5.1
Corn oil meal	4.0	1.3	3.6	4.0	1.3	6.7	5.8
Cottonseed meal	3.9	1.2	4.6	2.6	1.2	2.5	4.3
Cowpeas	9.1	0.7	5.4	3.6	[illegible].4	4.5	5.1
Crab meal	4.4	1.6	3.8	3.2	0.9	3.8	4.7
Distillers dried corn grains, with solubles	2.6	1.9	6.4	3.5	0.4	2.3	6.0
Distillers dried corn grains, without solubles	3.4	1.5	2.3	1.1	0.8	3.4	4.6
Distillers dried rye grains, with solubles	4.1	1.6	5.3	4.5	1.2	2.0	6.6
Distillers dried wheat grains, with solubles	2.8	1.7	6.6	3.5	1.4	2.1	6.6
Distillers solubles, dried, corn	3.2	2.1	5.3	3.5	0.7	2.5	5.3
Distillers solubles, dried, rye	1.7	1.4	4.8	3.1	0.6	1.7	5.4
Distillers solubles, dried, sorghum	3.4	1.9	6.8	3.8	1.1	3.4	7.6
Distillers solubles, dried, wheat	2.1	1.2	5.1	3.0	1.5	2.1	4.5
Fish meal, all analyses	10.4	3.0	4.2	4.6	1.1	3.0	5.7
Fish meal, herring	10.1	2.8	3.6	3.6	1.2	2.9	4.4
Fish meal, menhaden	8.6	2.9	4.3	4.7	1.0	2.6	5.8
Fish meal, redfish	11.6	3.2	4.4	4.6	1.1	3.0	5.8
Fish meal, salmon, flame dried	10.8	2.7	3.5	4.7	0.8	3.2	6.6
Fish meal, sardine	9.1	...	3.1	4.0	0.8	...	...
Fish solubles, condensed	8.0	3.3	4.3	3.8	2.2	...	4.8
Fish solubles, dried	6.3	1.8	2.5	2.1	0.7	1.5	3.9
Hominy feed	3.8	0.9	3.3	3.3	0.9	4.2	4.2
Linseed meal	3.7	1.3	4.2	3.4	1.4	2.8	4.8
Liver meal, animal	7.2	1.9	4.4	3.9	0.9	2.6	6.3
Meat scrap, 55% protein	6.9	1.5	3.5	3.3	0.5	1.6	4.7
Meat and bone scrap, 50% protein	7.0	1.4	3.6	3.6	0.4	...	4.8
Milk, cow's	7.6	2.1	4.7	4.8	1.5	...	7.3
Milk, cow's colostrum	7.9	1.8	4.5	7.0	1.8	...	8.0
Milk, ewe's	8.0	2.6	5.0	4.7	1.5	...	7.6
Milk, mare's	6.8	2.1	5.0	4.7	1.3	...	7.9
Milk, sow's	6.8	2.0	4.6	5.0	1.3	...	6.1
Milo grain	2.4	0.9	4.6	2.8	0.8	4.1	4.7
Oat grain	3.2	1.5	6.2	3.3	1.2	3.6	5.7
Oat meal, or rolled oats	3.7	1.2	4.3	3.1	1.2	4.3	4.3
Oat mill by-product	4.9	2.4	4.9	4.9	2.4	4.9	4.9
Pea seed, field	5.1	0.9	...	...	0.8	...	...
Peanut oil meal, solvent process	4.9	0.8	5.7	3.2	1.1	3.9	6.0
Rice, polished	3.5	3.6	...	...	...	...	...
Rice bran	4.0	...	...	3.2	0.8	...	...
Rice polishings	3.9	...	...	2.3	0.8	...	...
Rye grain	3.6	1.3	...	1.1	...	...	...

TABLE Xb. Percentages of amino acids in **protein** of feeds—*continued.*

Feeding stuff	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Safflower-seed oil meal, well-hulled	3.1	1.6	...	1.9	...	...	...
Sesame oil meal	2.8	2.7	4.6	3.7	1.4	4.6	5.0
Skimmilk, dried	8.5	2.4	4.5	4.2	1.2	3.9	6.6
Sorghum gluten feed	3.2	1.2	4.0	3.2	0.8	...	5.2
Sorghum gluten meal	1.7	1.7	6.3	3.4	1.0	...	6.0
Soybean oil meal, expeller process	6.2	1.7	4.8	3.9	1.4	3.2	5.0
Soybean oil meal, solvent process	6.4	1.3	4.8	3.7	1.3	3.1	5.3
Sunflower-seed oil meal	3.6	3.2	...	...	1.2	...	...
Tankage, digester, 60% protein	6.7	1.3	4.5	4.0	1.2	...	7.1
Wheat bran	3.8	0.6	3.0	2.4	1.8	2.6	4.3
Wheat flour	2.8	0.9	5.6	2.8	0.9	1.9	4.6
Wheat germ	6.0	1.1	3.1	3.1	1.1	3.1	4.2
Wheat grain, hard spring	2.0	1.1	4.5	2.2	0.8	...	4.0
Wheat red dog	3.4	0.6	2.8	2.8	1.1	2.8	4.5
Wheat standard middlings	4.1	1.2	4.1	3.5	1.2	2.5	4.6
Whey, dried	8.6	1.6	3.1	6.3	1.6	2.3	5.5
Whey product, dried	...	0.7	0.7	3.3	0.7	1.3	2.0
Yeast, brewers', dried	6.7	1.5	4.0	4.7	1.1	3.3	5.2
Yeast, torula, dried	8.2	1.7	6.5	5.6	1.1	4.5	6.2

Table XI. Productive and Metabolizable Energy of Feeds for Poultry

In formulating rations for poultry, productive-energy values, or net-energy values, of feeds are often used. (1530) The first column of figures in the following table gives the productive-energy values of the more important poultry feeds, as estimated by Fraps from his experiments. (Fraps, Texas Bul. 678.) The values are stated in terms of Calories of productive energy per pound of feed.

The second column of figures gives the productive-energy values of these feeds, as recently computed by Titus from the data of Fraps and others and from the digestible nutrients for poultry in these feeds. (Titus, Scientific Feeding of Chickens, 2nd Edition, 1955.)

The last column of figures gives the metabolizable-energy values of these feeds. As stated in Chapter XXXVII, recent studies indicate that metabolizable-energy values are more reliable than productive-energy values for poultry. (1532)

The metabolizable-energy values marked with an asterisk are values actually determined in recent New York experiments. (Hill, N.Y. mimeo. rpt., 1956; Anderson, Proceedings 1956 Cornell Nutrition Conference for Feed Manufacturers.) The values marked with a dagger are values computed by Titus from the digestible nutrients for poultry in these feeds, and from other data. (Titus, Scientific Feeding of Chickens, 2nd Edition, 1955.)

Table XI. Productive and metabolizable energy of feeds for poultry

Feeding stuff	Productive energy, Fraps' values	Productive energy, Titus' values	Metabolizable energy
	Cal. per lb.	Cal. per lb.	Cal. per lb.
Alfalfa, green, fresh	...	116	217 †
Alfalfa meal, 20% protein	314	385	619 †
Alfalfa meal, 17% protein	...	217	310 *
Animal fat	...	2,878	3,280 *
Barley	811	813	1,320 *
Beans, navy, cooked	792	...	...
Beet pulp, dried	220	207	279 †
Brewers' dried grains	1,005	747	1,144 †
Buttermilk, dried	707	786	1,247 †
Cabbage	...	64	118 †
Clover hay, red	405	299	...
Coconut meal, exp. or hydr.	619	585	799 †
Corn, dent, Grade No. 2	1,092	1,079	1,550 *
Corn feed meal	1,009	999	1,386 †
Corn gluten feed	565	564	766 †
Corn gluten meal	839	821	1,095 †
Cottonseed meal, 43% protein	694	800	1,159 †
Cowpeas	...	883	1,175 †
Distillers corn solubles, dried	853	1,020	1,395 †
Field peas	...	890	1,182 †
Fish meal	898	941	910 *
Hegari	1,048	1,114	1.597 †
Hominy feed	831	...	...
Kafir	1,059	1,082	1,502 †
Linseed meal, exp.	571	507	692 †
Liver meal	1,092	1,031	1,373 †
Meat scrap, 55% protein	724	949	1,249 †
Meat and bone scrap, 50% protein	724	874	800 *
Milk, cow's	...	203	284 †
Millet, proso	985	975	1,362 †

TABLE XI. Productive and metabolizable energy of feeds for poultry—*continued.*

Feeding stuff	Productive energy, Fraps' values	Productive energy, Titus' values	Metabolizable energy
	Cal. per lb.	Cal. per lb.	Cal. per lb.
Milo	1,119	1,099	1,470 *
Molasses, cane	714	. . .	. . .
Oats	760	810	1,220 *
Oat meal or groats	1,151	1,162	1,630 *
Peanut meal	861	856	1,134 †
Potatoes	. . .	215	321 †
Rice, rough	777	786	1,216 †
Rice bran	717	698	1,072 †
Rice polishings	984	1,044	1,555 †
Rye	814	886	1,319 †
Skimmilk, dried, not over 5% of mash	525	765	1,232 †
Skimmilk, liquid	. . .	107	145 †
Soybeans, cooked	. . .	1,023	. . .
Soybean oil meal, solvent, 50% protein	. . .	790	1,142 †
Soybean oil meal, solvent, 44% protein	565	761	1,000 *
Sunflower-seed oil meal, unhulled	. . .	580	772 †
Sweet potatoes	. . .	269	425 †
Tankage, 60% protein	676	814	1,198 †
Wheat	1,024	897	1,490 *
Wheat bran	478	494	510 *
Wheat gray shorts, or flour middlings	720	756	1,190 *
Wheat red dog	983	. . .	1,380 *
Wheat standard middlings, or brown shorts	581	694	810 *
Whey, dried, not over 5% of mash	490	786	1,242 †
Yeast, brewers', dried	476	572	1,123 †

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